REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	AUG 1997	FINAL 01/01/93--12/01/93

4. TITLE AND SUBTITLE WRIGHT LABORATORY SUCCESS STORIES

A REVIEW OF 1993

5. FUNDING NUMBERS
C - - -
PE
PR
TA
WU

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
PLANS AND PROGRAMS DIRECTORATE
WRIGHT LABORATORY
AIR FORCE MATERIEL COMMAND
WRIGHT PATTERSON AFB OH 45433-7523

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
PLANS AND PROGRAMS DIRECTORATE
WRIGHT LABORATORY
AIR FORCE MATERIEL COMMAND
WRIGHT PATTERSON AFB OH 45433-7523
POC: MICHAEL GROMOSIAK, WL/DOR (937) 255-4119

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
WL-TR-97-6006

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

SUCCESS STORIES FROM 1993 THAT RECOGNIZE THE ACCOMPLISHMENTS AND COMBINED EFFORTS OF WRIGHT LABORATORY SCIENTISTS AND ENGINEERS. STORIES HAVE BEEN SELECTED FROM THE FOLLOWING CATEGORIES: TECHNOLOGY TRANSITION--TECHNOLOGY THAT HAS ACHIEVED APPLICATION ON A DOD SYSTEM IN DEVELOPMENT OR OPERATION; TECHNOLOGY TRANSFER--TECHNOLOGY TRANSFERRED FROM THE LABORATORY TO THE PRIVATE SECTOR; TECHNICAL ADVANCEMENT --MAJOR INNOVATIVE TECHNOLOGICAL ADVANCEMENTS THAT OFFER SIGNIFICANT POTENTIAL FOR EXISTING & FUTURE AF SYSTEMS; AND, PEER RECOGNITION--EXTERNAL AWARDS OR RECOGNITIONS BY THE SCIENTIFIC COMMUNITY AT LARGE, CONCERNING ADVANCEMENTS IN TECHNOLOGY TRANSITION, TRANSFER OR TECHNICAL ACHIEVEMENT.

14. SUBJECT TERMS

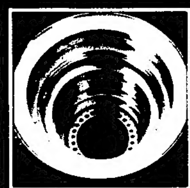
15. NUMBER OF PAGES
160

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

1993

WRIGHT LABORATORY SUCCESS STORIES



19970828 101

Air Force
SCIENCE & TECHNOLOGY

For more than 65 years, vital aerospace research and advanced technology developments in materials, avionics, armament, engines, flight dynamics, solid state electronics and integrated manufacturing have been performed by Wright Laboratory. This work has enabled our Air Force to establish and maintain its acknowledged position as the world's most technically advanced and capable in the world.

Each year we highlight the best and brightest of our laboratory efforts with "Success Story" profiles. I invite you to explore the diversity of innovative and exciting technological discovery and development ongoing at Wright Laboratory.

In a rapidly changing Defense environment, a new challenge has been accepted by Wright Laboratory. That is to dramatically expand laboratory accessibility to the commercial marketplace, offering a rich and powerful resource to America's private sector.

This expanded laboratory focus is critical in helping the country become more economically competitive. Our laboratory continues to selectively nurture the most promising array of aerospace technologies. Today those technologies are the ones that meet the needs of our fighting forces and have potential in the commercial sector.

Should you see a Wright Laboratory "Success Story" you want to know more about, I hope you will contact us so we might share the details.

David A. Herrelko

David A. Herrelko
Colonel, USAF
Commander
Wright Laboratory

1993 Wright Laboratory Success Stories

Table of Contents

TITLE	PAGE
Introduction	iv
Maintenance Free Aircraft Battery	1
High Speed Aircraft Tire Modeling/Test Methods	3
Award for Operational Effectiveness Improvement	5
B-1B Extended Life Windshield Program	7
Flight Control Maintenance Diagnostics (FCMDs)	9
New High Temperature Composite Material	11
Electronic Cooling Fluid Transition	13
Cryogenic Heat Pipe (CRYOHP) Flight Experiment	15
Air Force Office of Scientific Research (AFOSR) Star Team Awards	17
Real Time, Piloted Tactical Mission Simulation (TMS)	19
Chemically Vapor Deposited (CVD) Silicon Carbide	21
New Aircraft Wire Insulation	23
Ultrasonic Bird Repelling Device Utility	25
Advanced Repair Techniques for Static Jet Engine Components	27
Air Force Materials Processing Research Saves $500,000	29
New Hydraulic Fluid Increases Pilot Safety	31
New Manufacturing Processes for Infrared Detector Arrays	33
Pilot's Associate Program	35

(continued on next page...)

TITLE	PAGE
Reliable Optical Card-Edge Connector (ROC)	37
Rigid Rod Polymer Technology Transfer	39
Robotic Engine Manifold Cleaning Cell (REMCC)	41
Award for Shuttle Orbiter Vehicle Support	43
Vortex Flow Control (VFC)	45
New Long Service Life Hybrid Ball Bearings	47
New Holographic Wafer Inspection Technology	49
Rapid Repair of Integral Fuel Tanks	51
In-Situ Sensor Control of Crystal Growth Parameters	53
High Power Density Microwave Heterojunction Bipolar Transistors	55
Complementary Heterostructure Field Effect Transistor Technology	57
New Titanium Casting Technology Saves Weight and Lowers Costs	59
Air Force Casting Model Helps U.S. Industry Become More Competitive	61
Drive-Reinforcement (D-R) Learning Controller Applied to Robotics	63
New Electro-Optical Crystals Improve Countermeasure Systems	65
Electrical Properties of Advanced Transistor Materials	67

TITLE	PAGE
Hybrid Laminar Flow Control Team Recipient of the Nelson P. Jackson Aerospace Award	69
Air Force Aluminum Extrusion Technology Will Save Industry Over $25 Million	71
Finger-Mounted Laser Technology Transfer	73
Advanced 0.35mm Integrated Circuit for Massively Parallel Processing (MPP)	75
Development, Patent of Automated Composite Curing Process Earns Royalty Dividends	77
Non-Cooperative Vector Scoring System	79
Laser Velocimetry (LV) Measurements for Computational Fluid Dynamics (CFD) Code Validation	81
Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL)	83
Integrated Data Strategy (IDS) Saves Engineers Time, Money	85
New Metal Alloy Has Military and Commercial Applications	87
Government, Industry Consortium to Improve High Temperature Composite Materials	89
Automated Manufacturing Process Lowers Integrated Circuit Costs	91
Metal Oxide Semiconductor (MOS) Controlled Thyristor (MCT) - R&D 100 Award	93

(continued on next page...)

TITLE	PAGE
Cockpit Solar Shield Design Development Receives Recognition	95
Ultra Pure Silicon Improves Infrared Sensors and Semicondutor Devices	97
Hard Target Fuze for AC-130H Gunships	99
Auto Ground Collision Avoidance System (GCAS)	101
Improved Fuel Tank Sealing Process for F-111	103
Risk Analysis for Aging Aircraft	105
Dual Award Winner for Contributions to Combustion Diagnostics	107
Better, Safer and Cheaper Binder for Propellants	109
Hazardous Material in Fuel Tank Sealants Eliminated	111
New Process for Applying Composite Resin Improves Composite Materials and Reduces Chemical Usage	113
C-5A Upper Forward Fuselage Cracking Solution	115
Large Single Crystals of Silicon Carbide Provide More Robust Electronics	117
Intraformation Positioning System (IFPS)	119
Materials Directorate Validates Laser for Industrial Applications	121
New Process Improves Superconductor Materials	123

TITLE	PAGE
New Aluminum Alloy Exhibits Improved Stress Corrosion Resistance	125
Modular Data Acquisition and Recording System (MDARS)	127
Thermoplastic Composite Material Improves Stealth Fighter Performance	129
Improved Grease to Save Millions for Cruise Missile Maintenance	131
Manufacturing Technology for Transmit/Receive Modules	133
Metal Matrix Composite (MMC) Compressor Rotor - R&D 100 Award	135
New Composite Material Improves F-117A Fuselage Trailing Edge	137
Improved Process Reduces Cost of Missile Wings	139
New Coatings Improve Infrared Window Durability	141
Advanced Metal Matrix Microwave Packages for Multi-Chip Assemblies	143
Mobile Automated Scanner (MAUS III) Saves Time	145
Binary Optics Laser Scanner	147
New F-16 Prototype Canopy System	149
Appendix A: Acronym List	A-1

Introduction

Over 200 Air Force Science and Technology "Success Stories" from Wright Laboratory have been presented over the past five years. The individual stories most often represent the combined effort of several scientists and engineers working as a team. This basic and applied research, plus the follow-on technology development described in a "Success Story", are key elements of the continued success of the Wright Laboratory mission.

This year's "Success Stories" were selected from one or more of the following categories:

Technology Transition: Technology that has achieved application on a Department of Defense system in development or operation or that has provided "quick-reaction" response to problems or needs of field organizations (see Table I).

Technology Transfer: Technology that has transferred from the laboratory to the private sector, to include: industry, academia, and state and local governments (see Table II).

Technical Achievement: Major innovative technological advancements that offer significant potential for existing and future Air Force systems (see Table III).

Peer Recognition: External awards or recognitions by the scientific community at large, concerning technology advancements in the areas of Technology Transition, Technology Transfer or Technical Achievement (see Table IV).

To receive more information on the "Success Stories" contained in this document by the experts involved, or to learn about other activities at Wright Laboratory, please contact: WL/DOR, Wright Laboratory, Wright-Patterson AFB, OH 45433-6523, Tel. (513) 255-4119.

TABLE I. 1993 TECHNOLOGY TRANSITION SUCCESS STORIES

Success Story Title	Page #
Maintenance Free Aircraft Battery	1
High Speed Aircraft Tire Modeling/Test Methods	3
Award for Operational Effectiveness Improvement	5
B-1B Extended Life Windshield Program	7
Flight Control Maintenance Diagnostics	9
New High Temperature Composite Material	11
Electronics Cooling Fluid Transition	13
Real Time, Piloted Tactical Mission Simulation (TMS)	21
New Aircraft Wire Insulation	23
Ultrasonic Bird Repelling Device Utility	25
Advanced Repair Techniques for Static Jet Engine Components	27
Air Force Materials Processing Research Saves $500,000	29
New Manufacturing Processes for Infrared Detector Arrays	33
Reliable Optical Card-Edge Connector (ROC)	37
Rigid Rod Polymer Technology Transfer	39
Robotic Engine Manifold Cleaning Cell (REMCC)	41
Award for Shuttle Orbiter Vehicle Support	43
New Holographic Wafer Inspection Technology	49
High Power Density Microwave Heterojunction Bipolar Transistors	55
Air Force Casting Model Helps U.S. Industry Become More Competitive	61
Drive-Reinforcement (D-R) Learning Controller Applied to Robotics	63
Electrical Properties of Advanced Transistor Materials	67
Non-Cooperative Vector Scoring System	79
Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL)	83
Integrated Data Strategy (IDS) Saves Engineers Time, Money	85
New Metal Alloy Has Military and Commercial Applications	87
Hard Target Fuze for AC-130H Gunships	99
Auto Ground Collision Avoidance System (GCAS)	101
Improved Fuel Tank Sealing Process for F-111	103
Risk Analysis for Aging Aircraft	105
Hazardous Material in Fuel Tank Sealants Eliminated	111
C-5A Upper Forward Fuselage Cracking Solution	115

(continued on next page...)

TABLE I. 1993 TECHNOLOGY TRANSITION SUCCESS STORIES (CONT'D)

Success Story Title	**Page #**
Intraformation Positioning System (IFPS)	119
New Aluminum Alloy Exhibits Improved Stress Corrosion Resistance	125
Modular Data Acquisition and Recording System (MDARS)	127
Thermoplastic Composite Material Improves Stealth Fighter Performance	129
Improved Grease to Save Millions for Cruise Missile Maintenance	131
Manufacturing Technology for Transmit/Receive Modules	133
New Composite Material Improves - F-117A Fuselage Trailing Edge	137
Improved Process Reduces Cost of Missile Wings	139
New Coatings Improve Infrared Window Durability	141
Mobile Automated Scanner (MAUS III) Saves Time	145
New F-16 Prototype Canopy System	149

TABLE II. 1993 TECHNOLOGY TRANSFER SUCCESS STORIES

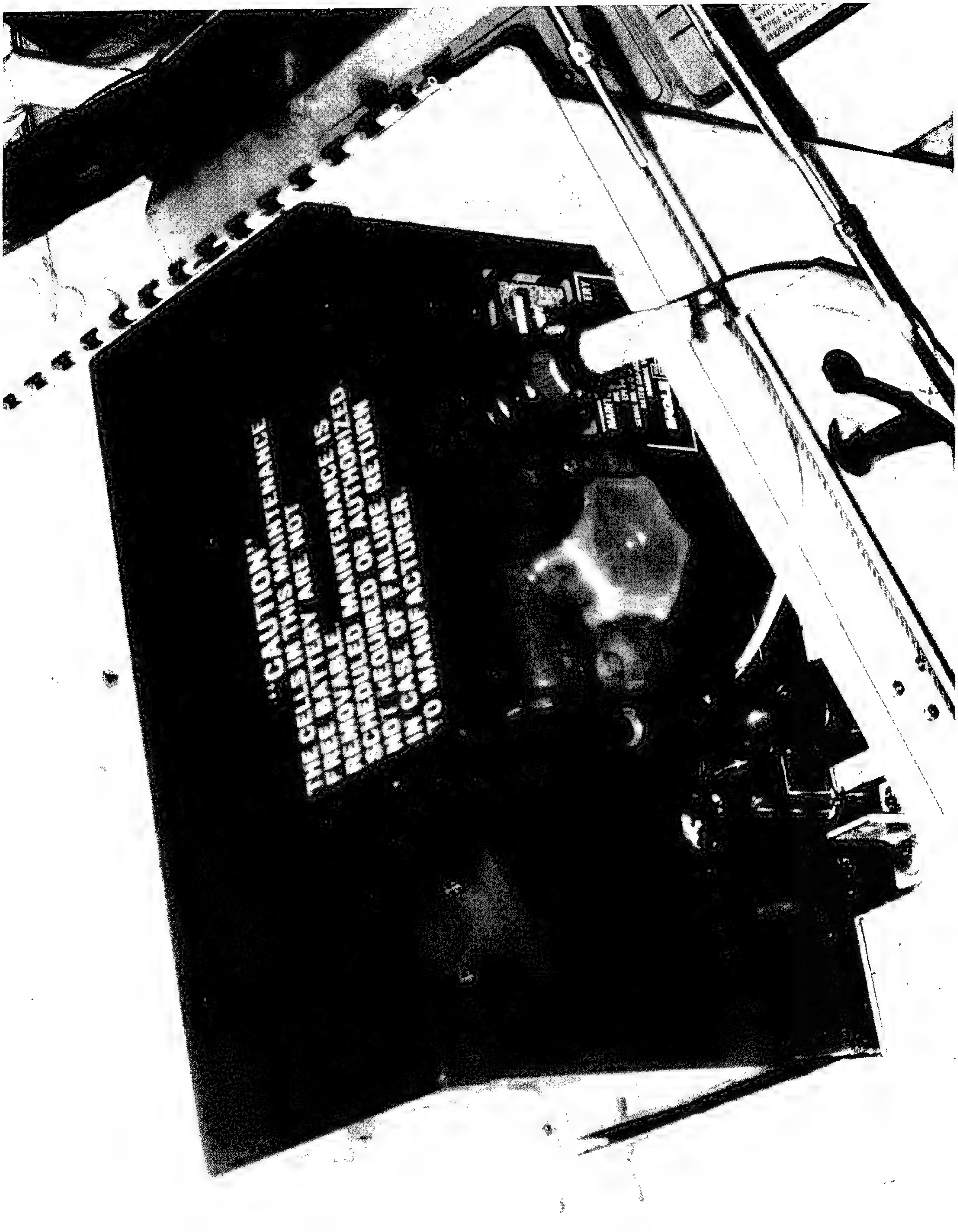
Success Story Title	**Page #**
Maintenance Free Aircraft Battery	1
High Speed Aircraft Tire Modeling/Test Methods	3
New Aircraft Wire Insulation	23
Rigid Rod Polymer Technology Transfer	39
New Holographic Wafer Inspection Technology	49
In-Situ Sensor Control of Crystal Growth Parameters	53
High Power Density Microwave Heterojunction Bipolar Transistors	55
Complementary Heterostructure Field Effect Transistor Technology	57
New Titanium Casting Technology Saves Weight and Lowers Costs	59
Air Force Casting Model Helps U.S. Industry Become More Competitive	61
Electrical Properties of Advanced Transistor Materials	67
Air Force Aluminum Extrusion Technology Will Save Industry Over $25 Million	71
Finger-Mounted Laser Technology Transfer	73
Development, Patent of Automated Composite Curing Processing Earns Royalty Dividends	77
New Metal Alloy Has Military and Commercial Applications	87
Government, Industry Consortium to Improve High Temperature Composite Materials	89
Ultra Pure Silicon Improves Infrared Sensors and Semiconductor Devices	97
Risk Analysis for Aging Aircraft	105
Materials Directorate Validates Laser for Industrial Applications	121
Manufacturing Technology for Transmit/Receive Modules	133

Table III. 1993 Technical Achievement Success Stories

Success Story Title	Page #
Maintenance Free Aircraft Battery	1
Award for Operational Effectiveness Improvement	5
Electronics Cooling Fluid Transition	13
Cryogenic Heat Pipe Flight Experiment (CRYOHP)	15
Chemically Vapor Deposited Silicon Carbide	19
Real Time, Piloted Tactical Mission Simulator (TMS)	21
Ultrasonic Bird Repelling Device Utility	25
New Hydraulic Fluid Increases Pilot Safety	31
Pilot's Associate Program	35
Reliable Optical Card-Edge Connector (ROC)	37
Rigid Rod Polymer Technology Transfer	39
Vortex Flow Control (VFC)	45
New Long Service Life Hybrid Ball Bearings	47
Rapid Repair of Integral Fuel Tanks	51
In-Situ Sensor Control of Crystal Growth Parameters	53
High Power Density Microwave Heterojunction Bipolar Transistors	55
Complementary Heterostructure Field Effect Transistor Technology	57
New Titanium Casting Technology Saves Weight and Lowers Costs	59
Drive-Reinforcement (D-R) Learning Controller Applied to Robotics	63
New Electro-Optical Crystals Improve Countermeasure Systems	65
Electrical Properties of Advanced Transistor Materials	67
Advanced 0.35mm Integrated Circuit for Massively Parallel Processing (MPP)	75
Laser Velocimetry (LV) Measurements for Computational Fluid Dynamics (CFD) Code Validation	81
New Metal Alloy Has Military and Commercial Applications	87
Automated Manufacturing Process Lowers Integrated Circuit Costs	91
Ultra Pure Silicon Improves Infrared Sensors and Semiconductor Devices	97
Better, Safer and Cheaper Binder for Propellants	109
New Process for Applying Composite Resin Improves Composite Materials and Reduces Chemical Usage	113
Large Single Crystals of Silicon Carbide Provide More Robust Electronics	117
New Process Improves Superconductor Materials	123
Modular Data Acquisition and Recording System (MDARS)	127
Thermoplastic Composite Material Improves Stealth Fighter Performance	129
Advanced Metal Matrix Microwave Packages for Multi-Chip Assemblies	143
Binary Optics Laser Scanner	147

Table IV. 1993 Peer Recognition Success Stories

Success Story Title	**Page #**
Award for Operational Effectiveness Improvement	5
Air Force Office of Scientific Research (AFOSR) Star Team Award	17
Award for Shuttle Orbiter Vehicle Support	43
Hybrid Laminar Flow Control Team Recipient of the Nelson P. Jackson Aerospace Award	69
Metal Oxide Semiconductor (MOS) Controlled Thyristor (MCT) - R&D 100 Award	93
Cockpit Solar Shield Design Development Receives Recognition	95
Dual Award Winner for Contributions to Combustion Diagnostics	107
Metal Matrix Composite (MMC) Compressor Rotor - R&D 100 Award	135
Advanced Metal Matrix Microwave Packages for Multi-Chip Assemblies	143


"CAUTION"
THE CELLS IN THIS MAINTENANCE
FREE BATTERY ARE NOT
REMOVABLE.
SCHEDULED MAINTENANCE IS
NOT REQUIRED OR AUTHORIZED.
IN CASE OF FAILURE RETURN
TO MANUFACTURER.

Maintenance Free Aircraft Battery

Payoff

The maintenance free nickel cadmium (NiCd) battery systems technology that is currently available permits scheduled maintenance intervals to be extended to cover four or five year programmed depot maintenance (PDM) cycles. As a result of this initiative, Oklahoma City-Air Logistics Center (OC-ALC) has let a contract to procure 200 of these battery systems for the B-52H aircraft fleet. The advanced 20 years maintenance free NiCd battery system will not require scheduled maintenance. It is estimated that the cost avoidance will be $0.5 billion over 20 years. An additional $0.5 billion in savings is estimated by drastically reducing sortie aborts that are attributed to failed batteries.

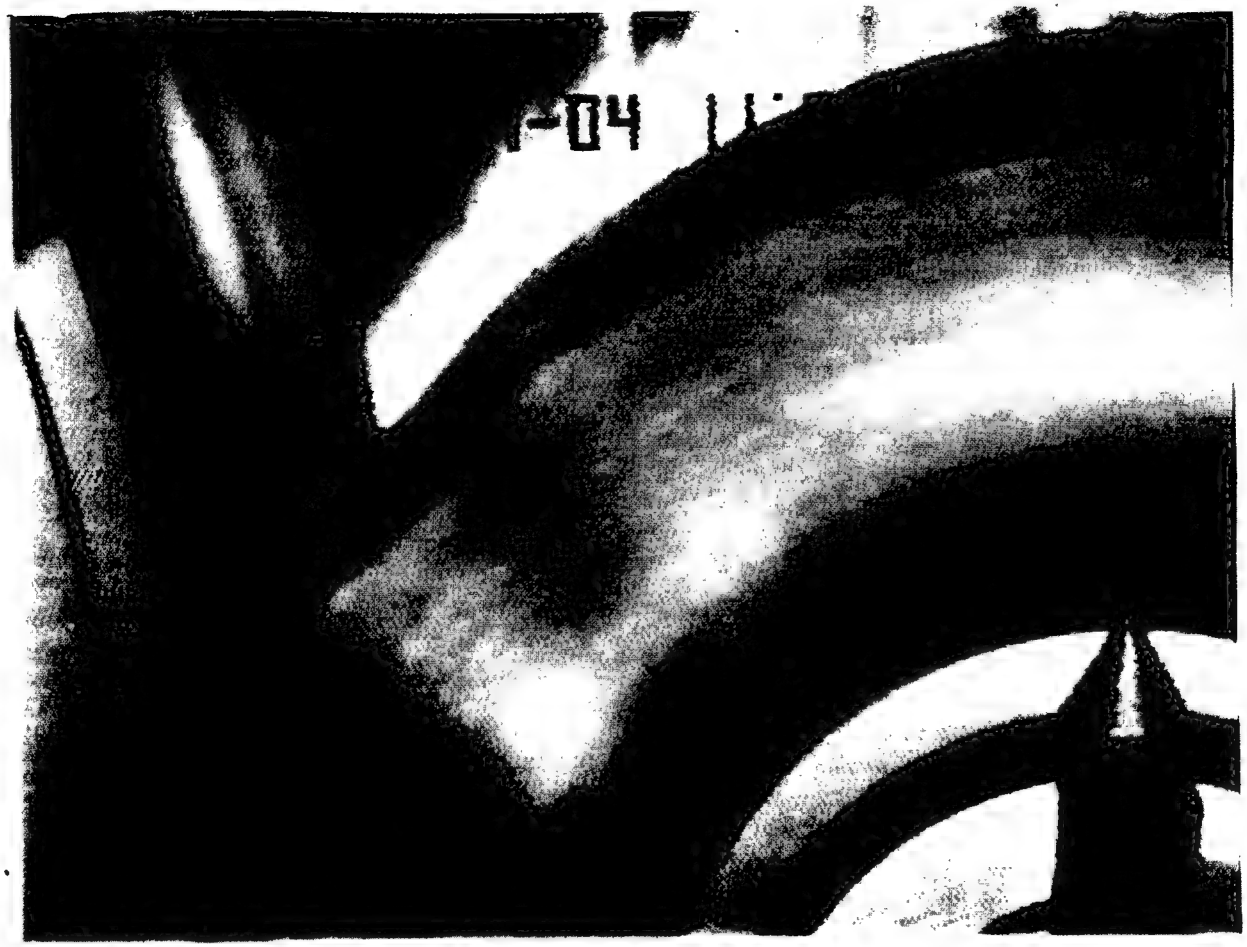
Accomplishment

Wright Laboratory's Aero Propulsion and Power Directorate has made considerable progress towards eliminating the maintenance requirement for the main battery aboard aircraft. The expense and logistics problems associated with battery maintenance are problems shared by the Air Force and the commercial aircraft industry. The progress and potential of the maintenance free battery development effort at Wright Laboratory is evident by the widespread interest and support from the using commands and commercial aircraft manufacturers.

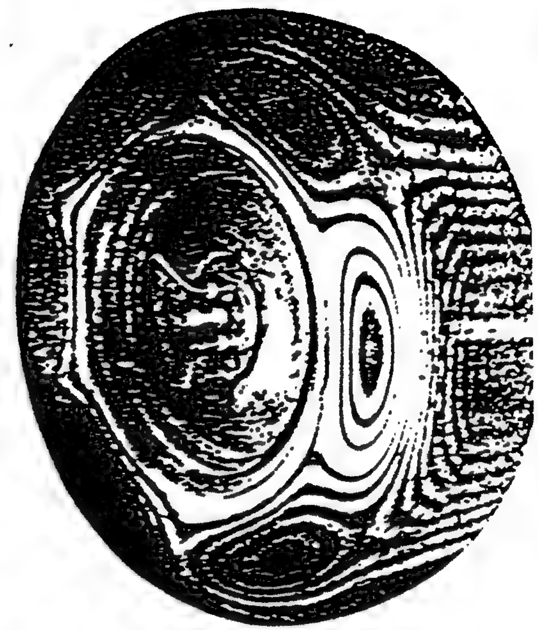
Background

Main aircraft batteries on today's aircraft require intensive maintenance procedures in flight line maintenance shops every 30-90 days. This problem is being vigorously addressed in a program to develop a 20 year maintenance free NiCd battery system. This effort evolved from an exploratory development program that proved the feasibility of a 1000 cycle (4 year) maintenance free battery system concept. Following the development of this experimental battery system, a successful flight compatibility was conducted aboard a B-52H aircraft for a period of nine months (approximately 400 maintenance free cycles). As a result of this initiative, OC-ALC has let a contract to procure 200 of these 4 years between interval battery systems for the B-52H aircraft fleet. In addition, the 645th Test Wing at Tinker AFB began flight compatibility testing on an E-3 AWACS. The aircraft was modified with two maintenance free battery systems on 30 September 1992 and to date has flown without incident. The success of the experimental effort, coupled with long life maintenance free data from satellite NiCd batteries, convinced the Aero Propulsion and Power Directorate to initiate an advanced effort to develop an aircraft battery system that required no maintenance for 20 years. This program started in July 1991 with an end date of 30 September 1994. Both of the maintenance free battery system program's end products are designed to have direct form, fit and function applicability to the following aircraft: E-3 AWACS, E-8 JSTARS, KC-135, C-17, B-1, B-2, F-22 and F-16. The 6.3 effort has produced long life and more performance efficient electrodes. These electrodes have become the new baseline for all of the contractors standard NiCd batteries.

Frame Grabber Method



Shadow Moire
Fringe Pattern



HIGH SPEED AIRCRAFT TIRE MODELING/TEST METHODS

Payoff

Advanced tire analytical modeling and test methodologies, such as Moire-Fringe measurement techniques, provide the ability to accurately predict a tire's standing wave (critical speed) characteristics, tire dynamics and tire life durability. These advancements provide tools and rules to enable the evaluation of high speed tire designs for supersonic aircraft and the space shuttle. NASA Johnson Space Center's Shuttle Operations and their tire vendors began utilizing these tools and rules in July 1992 to evaluate the high speed/high load capabilities of the current Orbiter tire design.

Accomplishment

The Vehicle Subsystems Division of Wright Laboratory's Flight Dynamics Directorate has advanced tire modeling effort to include ply-shear strain energy predictions, material modeling and advanced test methodologies, such as Moire-Fringe measurement techniques. This advanced technology has added new insight to the understanding of high speed tire dynamics and tire life durability.

Background

Air Force and NASA long range planning dictated aerodynamic and configuration characteristics necessary for single-stage-to-orbit hypersonic flight vehicle designs. This resulted in projected takeoff and landing speeds of 350 mph to 450 mph which are significantly higher than those of current supersonic aircraft and the space shuttle. Current tire technology designs have demonstrated high speed capability up to approximately 220 mph (with the highest proven speed equaling 305 mph). As a result of this technology gap, the Vehicle Subsystems Division and NASA Langley Research Center's Landing and Impact Dynamics Branch have been involved in high speed tire dynamics/tire wear research for the last several years. The Vehicle Subsystems Division's recent contributions in high speed aircraft tire modeling test studies addressed a number of computational issues and test methodologies. The advanced modeling for tire dynamics and ply-shear strain energy predictions, coupled with advanced test methodologies, have enabled accurate high speed tire design evaluation for predicting a tire's standing wave (critical speed) characteristics, dynamics and life durability. NASA Johnson Space Center's Shuttle Operations and their tire vendors began utilizing the techniques in July 1992. Evaluation of the high speed/high load capabilities of the current space shuttle orbiter tire design will enable larger payloads to be launched and safely recovered on future missions. This research work supports Logistics Need No.86060, "Extended Life and Reliable Tires for Fighter Aircraft".

Award for Operational Effectiveness Improvement

Payoff

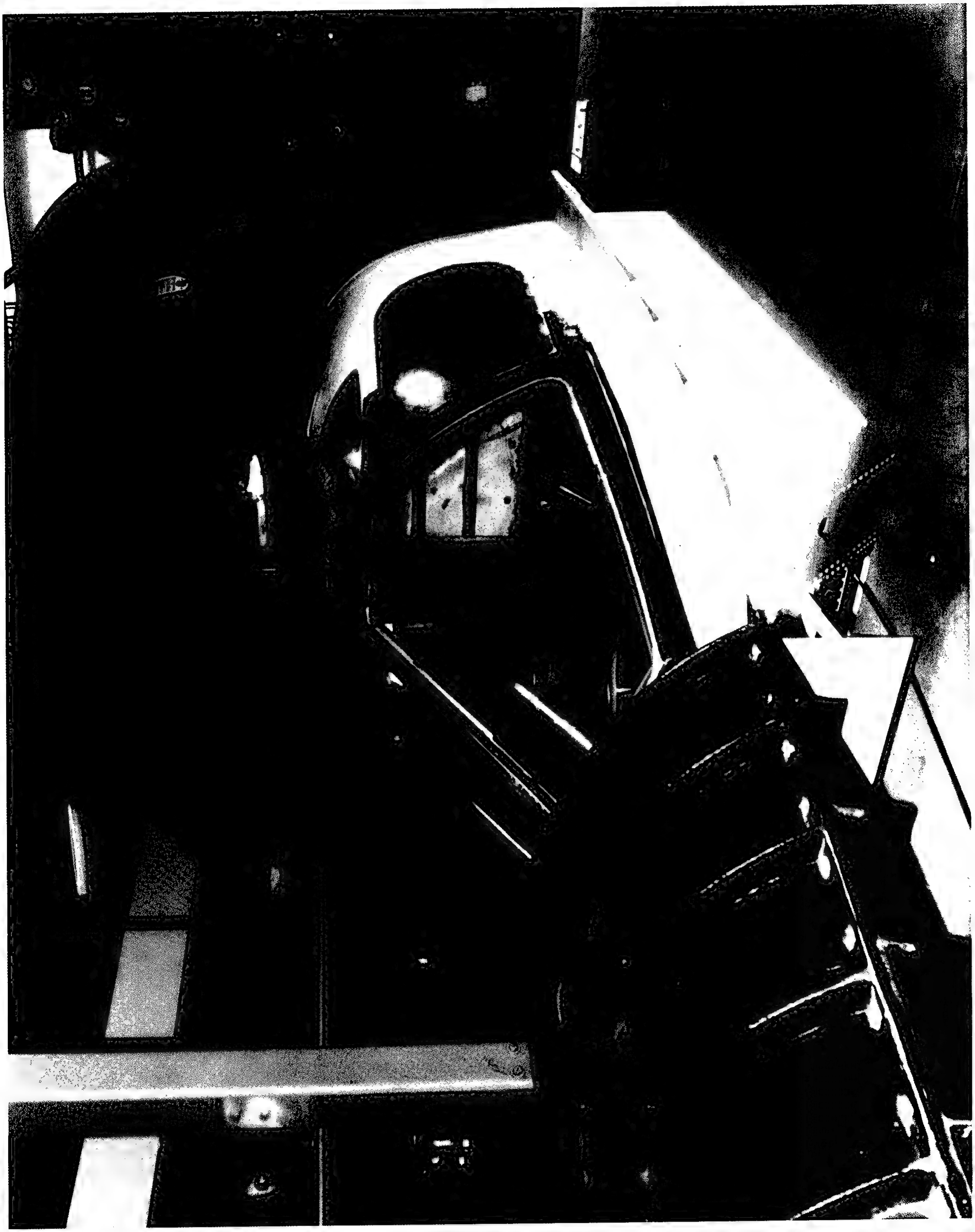
Mr. Nelson H. Forster was presented the 1992 Harold Brown Award for the successful transition of corrosion resistant coating technology to Air Force turbine engines. A study conducted by Oklahoma City- Air Logistics Center (OL-ALC) indicated that full transition will save the Air Force more than $14,000,000 annually in reduced costs for replacement bearings.

Accomplishment

Mr. Nelson H. Forster of Wright Laboratory's Fuels and Lubrication Division received the 1992 Harold Brown Award for his in-house work on corrosion resistant thin dense chrome (TDC) coatings which resulted in a substantial improvement in the operational effectiveness of turbine engine bearings. The award was presented by the Secretary of the Air Force, Dr. Donald Rice, at a Pentagon ceremony.

Background

The award was established in 1969 to recognize a significant achievement which led to, or demonstrated the potential of, a substantial improvement in the operational effectiveness of the Air Force. It is awarded annually to either a military or civilian member of the Air Force, engaged in any phase of research and development. Mr. Forster is the first Wright Laboratory recipient in the 23-year history of the award. The basis of the award for Mr. Forster was his research and development efforts with regard to TDC coatings for turbine engine bearings. Specifically, Mr. Forster conceived the idea of using TDC on bearings, conducted in-house testing to demonstrate its potential benefits, established and managed a contractual program to further develop and demonstrate the technology, and arranged for its incorporation in demonstrator engines and in the F101 Engine Component Improvement Program. In 1992, Mr. Forster with representatives from the Aeronautical Systems Center, OC-ALC, the Reliability and Maintainability Technology Improvement Program (RAMTIP) office, and the General Electric Company formulated a plan for transitioning the technology into the F101, F110, F118 and TF39 engines, which power the B-1, F-16, B-2 and C-5 aircraft respectively. The three year program was selected for funding by the RAMTIP office and was initiated in 1992.



B-1B Extended Life Windshield Program

Payoff

The new B-1B windshield designs provide a 100% increase in service life. On top of the savings from increased service life, $6 million was saved when unit windshield cost dropped over 50% compared to current production design. The implementation of a multiple imaging acceptance test procedure ensured delivery of windshields with acceptable multiple imaging characteristics. With a total of $1.9 million invested, the Air Force is projected to save $150 million over the life of the B-1B fleet. In 1992, the Oklahoma City-Air Logistics Center (OC-ALC) procured a total of 227 improved windshields for a fleet retrofit on a preferred spares basis.

Accomplishment

The Aircrew Protection Branch of the Flight Dynamics Directorate successfully led the B-1B Windshield Development team in developing and demonstrating prototype B-1B windshield designs which have doubled the service life of the current B-1B windshield. The team also developed an acceptance test procedure to control multiple imaging of the windshield.

Background

The current B-1B windshield has a service life of less than one year due to delamination of the glass outer ply. The resulting cost of ownership for the Air Force exceeds $10 million annually for spare parts alone. Additionally, the night time multiple imaging of objects viewed through the windshield presented a problem during night landing. In late 1988, a team consisting of OC-ALC, Air Combat Command (then Strategic Air Command), Armstrong Laboratory, B-1 System Program Office and Wright Laboratory, initiated the B-1B Extended Life Windshield Program to address the windshield's short service life. The team developed and demonstrated prototype designs that have doubled the current service life. The five windshield designs were successfully evaluated during operational flight testing at all four B-1B bases. Durability testing of the windshields at Wright Laboratory's Aircraft Transparency Durability Testing Facility at Wright Patterson AFB will result in the ability to procure windshields based on their durability. This is done by accelerated simulation of thermal and pressure environments which the B-1B windshield is subjected to during its operational life. In 1992, the OC-ALC procured a total of 227 improved windshields for fleet retrofit on a preferred spares basis.

Flight Control Maintenance Diagnostics (FCMDs)

Payoff

The flight control maintenance diagnostics (FCMDs) provides a validated and verified tool for flight line technicians to troubleshoot the F-16 digital flight control system. Technicians with varying skill levels can increase their diagnostic and maintenance productivity to the level of an expert using FCMDs technology. The use of FCMDs on the existing F-16C/D fleet is estimated at flight line savings of 2282 maintenance personhours per month and reductions of 43% in spare flight control parts.

Accomplishment

The Flight Dynamics Directorate's Flight Control Division, after extensive field tests at Luke AFB, demonstrated that a portable intelligent maintenance diagnostics tool can significantly improve aircraft availability. The FCMDs portable unit, used to troubleshoot the F-16 digital flight control system, assisted flight line technicians from various disciplines and skill levels with less than one hour's training to save 26% in overall diagnostic time and increase diagnostic accuracy by 92%. The methodology combined contractor and flight line expertise for the display and troubleshooting of aircraft wiring.

Background

The Air Force is facing an increasingly difficult task in maintaining its fleet of aging aircraft with a decreasing work force. The complexity and integration of new systems as well as the rising number of technical orders also contribute to the problem. The latest complications arise from the creation of composite forces with multiple aircraft types and the transition to a two level support and repair structure. The purpose of FCMDs was to test the idea that computers with knowledge based or expert system software could assist flight line personnel to do their job more efficiently. The complete F-16C/D Digital Flight Control System model including wiring and all diagnostic and repair procedures are contained in the FCMDs. The main measures of effectiveness in this area are "Maintenance Man Hours per Flight Hour" and the rates of "Cannot Duplicate and Retest OK" for line replaceable units. After three months of verification and six months of controlled comparison testing, the FCMDs proved that a portable intelligent diagnostics tool can significantly improve aircraft availability. This technology supports the new, joint ACC, AMC and AFMC Mission Need Statement for Enhanced Diagnostics to Minimize Erroneous removals.

New High Temperature Composite Material

Payoff

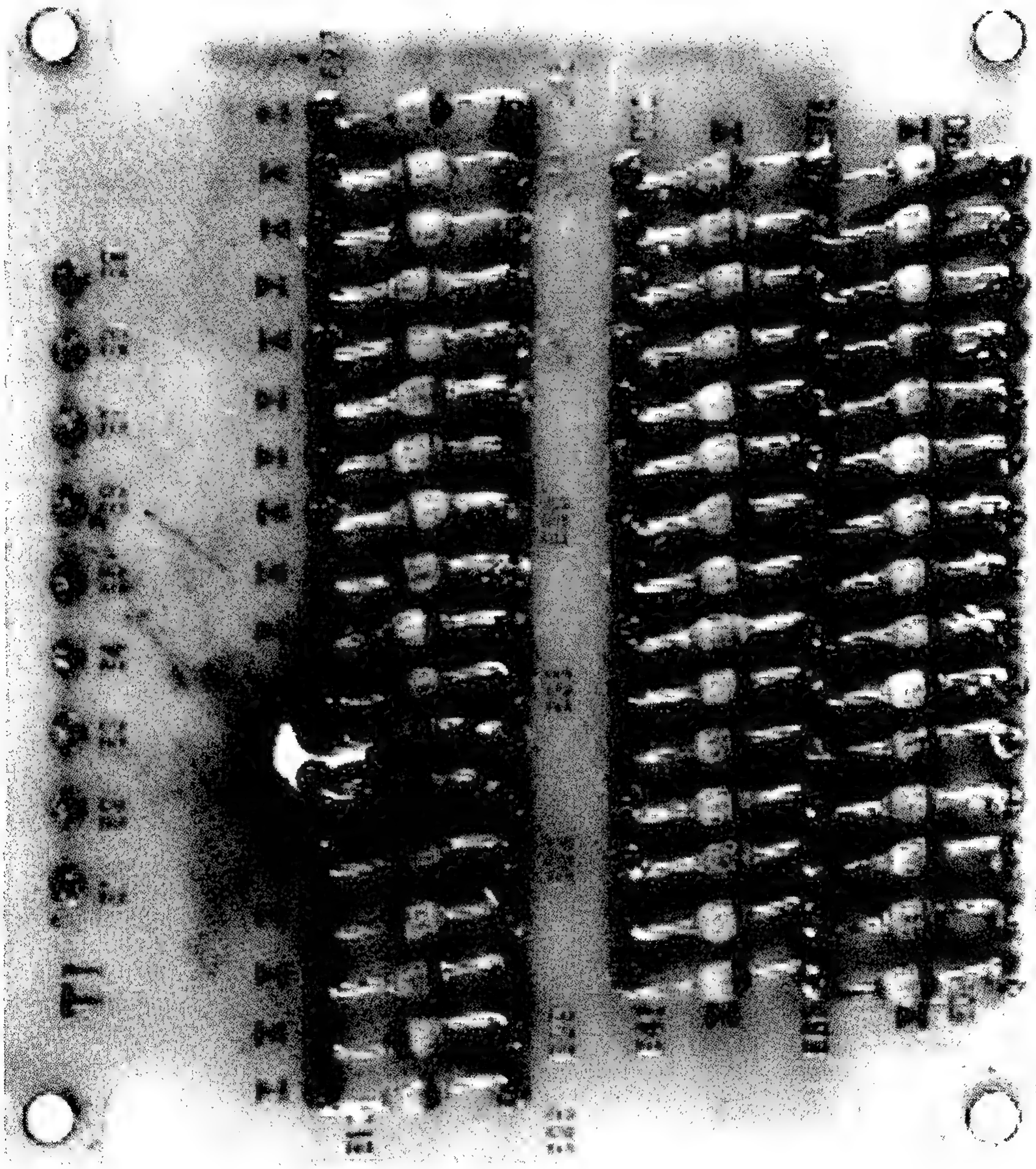
A structural wedge such as the one shown left is applicable to the B-2, F-117A and F-22. Fabricated using AFR700B resin, the wedge demonstrates an application of a material that offers aircraft and aircraft engine designers an advanced lightweight composite material for high temperature applications by increasing the temperature capability of organic matrix composites by 150°F. The Sacramento-Air Logistics Center has selected a structural wedge fabricated using AFR700B resin as a preferred spare for the F-117A.

Accomplishment

Wright Laboratory's Materials Directorate has developed a new organic composite material for use in high-temperature areas of Air Force aircraft. This material, based on AFR700B resin, will improve aircraft performance by making the aircraft lighter.

Background

Air Force aircraft performance requirements continually demand more of aerospace materials. They must be lighter and stronger while operating at increasing temperatures for longer periods. To help meet these demands, scientists in the Materials Directorate are coordinating several concurrent programs to develop, characterize and demonstrate AFR700B, a high-temperature, organic composite matrix material. Through in-house research, they are characterizing the material's physical and mechanical properties. At the same time, composite manufacturing engineers are adapting the qualitative process automation (QPA) expert system, developed by Wright Laboratory, to control the curing process of AFR700B. They have developed autoclave cure cycles for the composite which produce void-free laminates one-fourth inch thick. In addition, the Materials, Flight Dynamics and Aero Propulsion and Power Directorates are validating AFR700B's capability in various, but specific, applications through three separate but coordinated technology demonstration articles. Currently four companies (Hycomp, HEXCEL, SP Systems and ICI Fiberite) are producing AFR700B prepeg, while five companies (Northrop, Lockeed, etc.) are demonstrating structures. Future uses for this material range from aircraft structures and engine applications to extreme high temperature missile applications. By using AFR700B, a structural wedge has been developed which is applicable to current and future aircraft including the B-2, F-117A and F-22.



Electronics Cooling Fluid Transition

Payoff

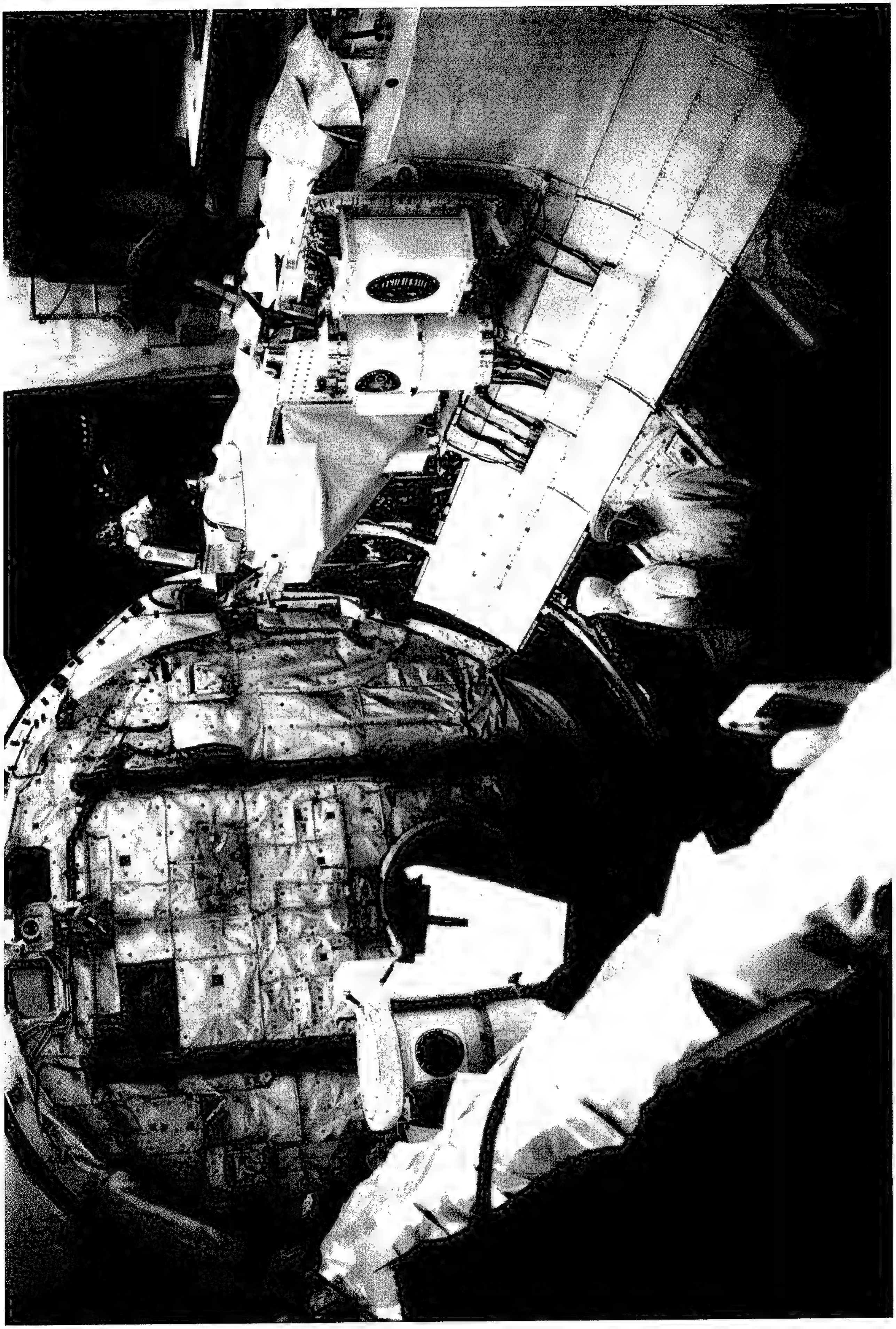
Operational problems for the B-1B caused by use of the traditional coolant included damage to electronic circuit boards. The new environmentally safe coolant solves this and other maintenance problems caused by the old coolant, thus improving aircraft safety and reliability while reducing operating costs. Life cycle cost savings for the B-1B are projected to reach $950M over a 25 year period. Additional cost savings will be realized as other systems switch to the new coolant.

Accomplishment

Researchers in Wright Laboratory's Materials Directorate have developed a new electronics cooling fluid that is non-toxic and costs 75 percent less than coolants that have been used to maintain electronic systems. The entire B-1B fleet has been converted to the new coolant and other systems are following suit.

Background

For more than 15 years silicate ester-based coolants have been used to maintain safe operating temperatures for aircraft electronic systems. As aircraft become more sophisticated, pilots must rely heavily on powerful electronic systems. These systems generate heat that, unless properly controlled, can cause problems. The traditional coolant started to cause maintenance problems for the Air Force's B-1B aircraft. Specifically, the aircraft's radar cooling systems started experiencing electronic arc failures, filter clogging and overheating. Researchers found the silicate ester-based coolant was reacting with moisture to form a silica gel and alcohol. The gel buildup on electrical boards was causing system failures through electronic arcing. It was also clogging coolant systems filters causing pump failures and subsequent component overheating. The alcohol formed in the reaction had a flash point dangerously below the operating temperature of most of the electronic system components. By switching to the synthetic hydrocarbon polyalphaolefin-based coolant (MIL-C-87252), Wright Laboratory scientists solved the B-1B's cooling system problems. Their new coolant is also nontoxic and costs 75 percent less than silicate ester-based coolants. Since it is compatible with all B-1B avionics and cooling system components, conversion to the new fluid is a simple drain-and-refill procedure. It has also been selected for use on the Air Force's LANTIRN system. The Navy's F-14s have been converted and the Air Force's F-15s and F-16s, along with the Navy's F-18s are being studied for conversion. The Army has also decided to use the coolant in the Patriot missile system.



Cryogenic Heat Pipe (CRYOHP) Flight Experiment

Payoff

With 0-g data now available from the cryogenic heat pipe (CRYOHP) flight experiment, that lifted off with the Space Shuttle Discovery on 2 Dec 92, excessive design margins which carry large penalties in cryogenic systems can be avoided and accurate modeling of steady-state and transient heat pipe behavior can be done for future missions. Future missions which include the Air Force's Follow-on Early Warning System (FEWS), SDI's Brilliant Eyes (BE) and Brilliant Pebbles (BP), and NASA's Earth Observation Satellite can now incorporate oxygen heat pipes in their systems with confidence.

Accomplishment

The CRYOHP flight experiment, sponsored by the Aero Propulsion and Power Directorate, lifted off with Discovery on 2 Dec 92. CRYOHP included the first oxygen heat pipes to fly in space and the first heat pipes to operate at less than 100° Kelvin in a 0-g environment. During the seven day mission, the experiment worked flawlessly and 100% of the required data was gathered. The oxygen heat pipes experiment directly supports the Air Force's FEWS Program sponsored by the Space and Missile Systems Center.

Background

CRYOHP is a joint DOD/NASA experiment that was funded by Wright Laboratory, NASA Goddard and the Strategic Defense Initiative (SDI) Office to fill a technology need in the area of cryogenic thermal management. These heat pipes are intended for removing heat from infrared (IR) sensors, instruments and space vehicles. The latest IR sensors and instruments require cooling at temperatures between 60° and 100° Kelvin to work most effectively. One of the most efficient devices for carrying heat away from these electronic components is a heat pipe using a cryogenic fluid. Oxygen is the best fluid for that temperature range but had never been tested in space and could not be adequately tested on the ground. A heat pipe is a closed vessel containing a fluid that absorbs heat through evaporation, transports the heat as a vapor and releases the heat upon condensing in a cooler region of the heat pipe called the condenser. The condensed fluid is than returned to the heated region (evaporator) by the capillary pumping of a wick. The result is an essentially constant temperature device capable of transporting vast amounts of heat over large distances with no moving parts. The CRYOHP experiment consisted of two independent heat pipes, one designed by TRW and the other by Hughes Aircraft, and was controlled by the ground team at NASA Goddard's Payload Operation Control Center. The mission objectives included: (1) Measuring 0-g cryogenic heat pipe transport capability; (2) Demonstrating 0-g pipe start-up from a supercritical condition; and (3) Correlating 0-g and 1-g data with existing analytical models.

Air Force Office of Scientific Research (AFOSR) Star Team Awards

Payoff

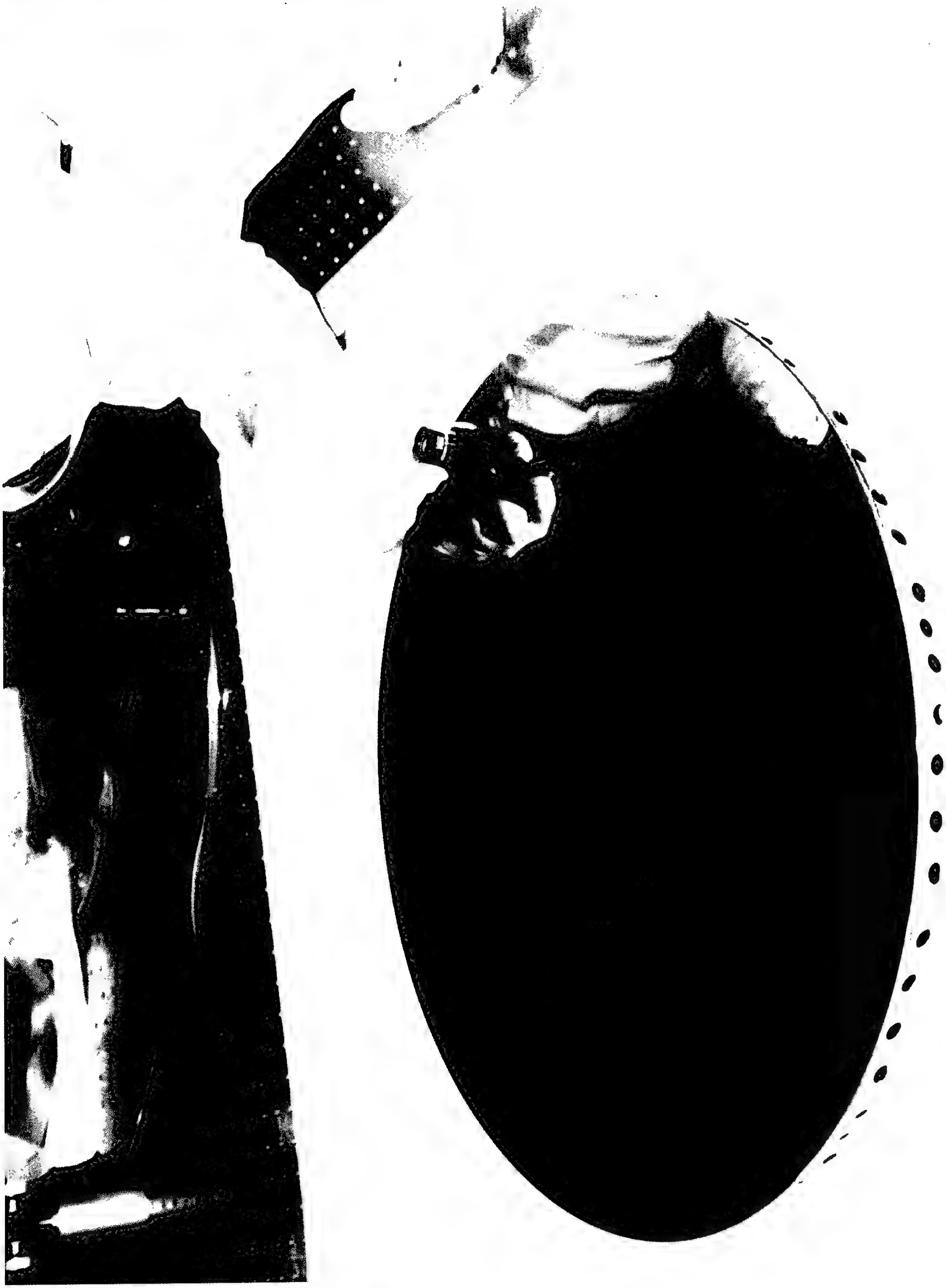
The accomplishments of the 1992 Wright Laboratory Star Team leaders and team members strengthen the critical role of basic research within the Air Force Science and Technology program. Each team has demonstrated, through their scientific and engineering excellence, world class status in their respective areas of research. They serve as a role model in showcasing Wright Laboratory's research achievements.

Accomplishment

Five Wright Laboratory teams of scientists and engineers received the 1992 Air Force Office of Scientific Research Star Award for excellence in basic research. The award rewards team achievements, fosters excellence within the research community and highlights the critical role of basic research within the Air Force's broad technology spectrum.

Background

As part of their annual review of basic research tasks in the laboratories, AFOSR selects teams of researchers that have proven, through their track record, world class status in their chosen areas of research. The work performed by the Fluids and Lubricants research team is led by Dr. Kent Eisentraut of the Materials Directorate. They have pioneered research in the development of new lubricants that must have a wide operating temperature range to satisfy gas turbine engines low temperature starting and operating conditions as well as provide the necessary lubrication for components in hot regions of the engines. Members of the Multivariable Control Systems team led by Dr. Siva Banda of the Flight Dynamics Directorate are recognized leaders in the development of practical and efficient robust control design techniques for multivariable systems. Robust control deals with stabilizing and controlling an aircraft or spacecraft despite uncertainties due to imperfect dynamic modeling. Development of the Processing Fundamentals of Metallic Structure Materials team's process models will enable Material Directorate's Dr. Lee Semiatin and his scientist to interpret and control the effects of temperature and deformation history in the design of complex theromechanical processes, such as pack rolling of sheet metal matrix composites. The Electronic and Optical Properties of Materials team led by Dr. Patrick Hemenger was selected for its leadership in fundamental research on semiconductor and nonlinear optical materials that are of high interest and payoff to the Air Force in future weapon systems. Significant achievements in the growth of new materials for advanced semiconductor devices and optical and electrical characterization and modeling of novel materials and device structures have been attained by the Characterization of Device Materials team led by Mr. Gary McCoy of the Solid State Electronics Directorate.



CHEMICALLY VAPOR DEPOSITED (CVD) SILICON CARBIDE

Payoff

Large, low cost, high quality mirrors made from chemically vapor deposited (CVD) silicon carbide (SiC) can now be produced for a variety of Air Force applications including, mirrors for space systems, solar collectors and concentrators, and astronomical telescopes. Producing bulk SiC via CVD provides optical and structural designers with a material that is highly polishable, thermally stable, extremely stiff, lightweight, non-toxic and durable.

Accomplishment

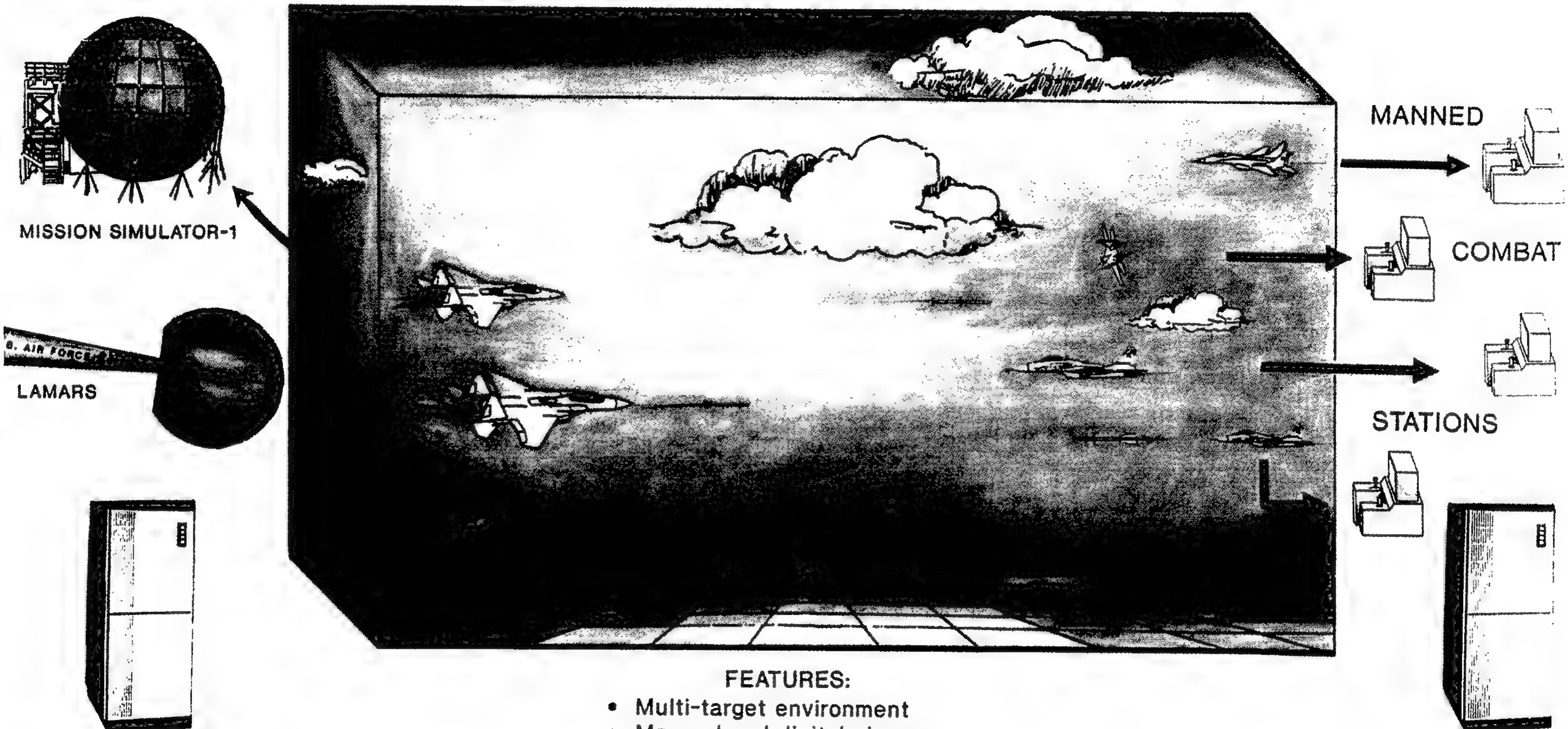
Accomplished under the sponsorship of the Materials Directorate, Morton International, Inc. has successfully developed a process to produce affordable, highly pure, large sheets of SiC with many properties superior to those of traditional reaction bonded or sintered ceramics. SiC compo-nents provided by the CVD process has exhibited superior mechanical, thermal, physical, and optical properties and surface finish on fractions of an angstrom.

Background

Materials used to make mirrors for space systems, solar collectors and concentrators and astronomical telescopes must be able to operate in ultraviolet, X-ray and laser environments without undergoing either surface degradation or excessive thermal distortion. The material that best meets those specifications is pure SiC. Conventional SiC production techniques did not produce the pure SiC needed. Historically, SiC pieces and components were made by hot pressing SiC powder mixed with a binding material. This process produced pieces that contained pores, voids and microcracks, which were not suitable for optical uses. Since the mid-1980s, Morton International Inc./Advanced Materials of Woburn, MA, working under contract with the Materials Directorate, has been researching and developing a process for fabricating large pieces of pure SiC. Their research has led to a CVD process that uses two gases (vapors) which are chemically reacted onto a temperature controlled surface to form deposits of solid pure SiC material called CVD Silicon Carbide. They have used the process to produce sheets of pure SiC measuring 1.5 meters in diameter. Not only does this process produce pure SiC, it can be used to make components in their desired shapes and near final dimensions. This reduces the amount of machining, polishing or other manufacturing operations necessary to produce the final part. The process can also be used to coat components with SiC to produce units with an even wider range of properties.

TACTICAL AIR COMBAT SIMULATION

A Safe, Cost Effective Air-to-Air Combat Research Tool



BLUE-SIDE COMPUTATIONS:
- AIRCRAFT MODELS
- MISSILE MODELS
- DIGITAL A/C LOGIC
- SENSOR MODELS

FEATURES:
- Multi-target environment
- Manned and digital players
- Realtime performance
- Detailed simulator crewstations
- High & medium fidelity modeling
- Advanced test director console
- Flexible H/W & S/W architecture

RED-SIDE COMPUTATIONS:
- AIRCRAFT MODELS
- MISSILE MODELS
- DIGITAL A/C LOGIC
- SENSOR MODELS

Real Time, Piloted Tactical Mission Simulation (TMS)

Payoff

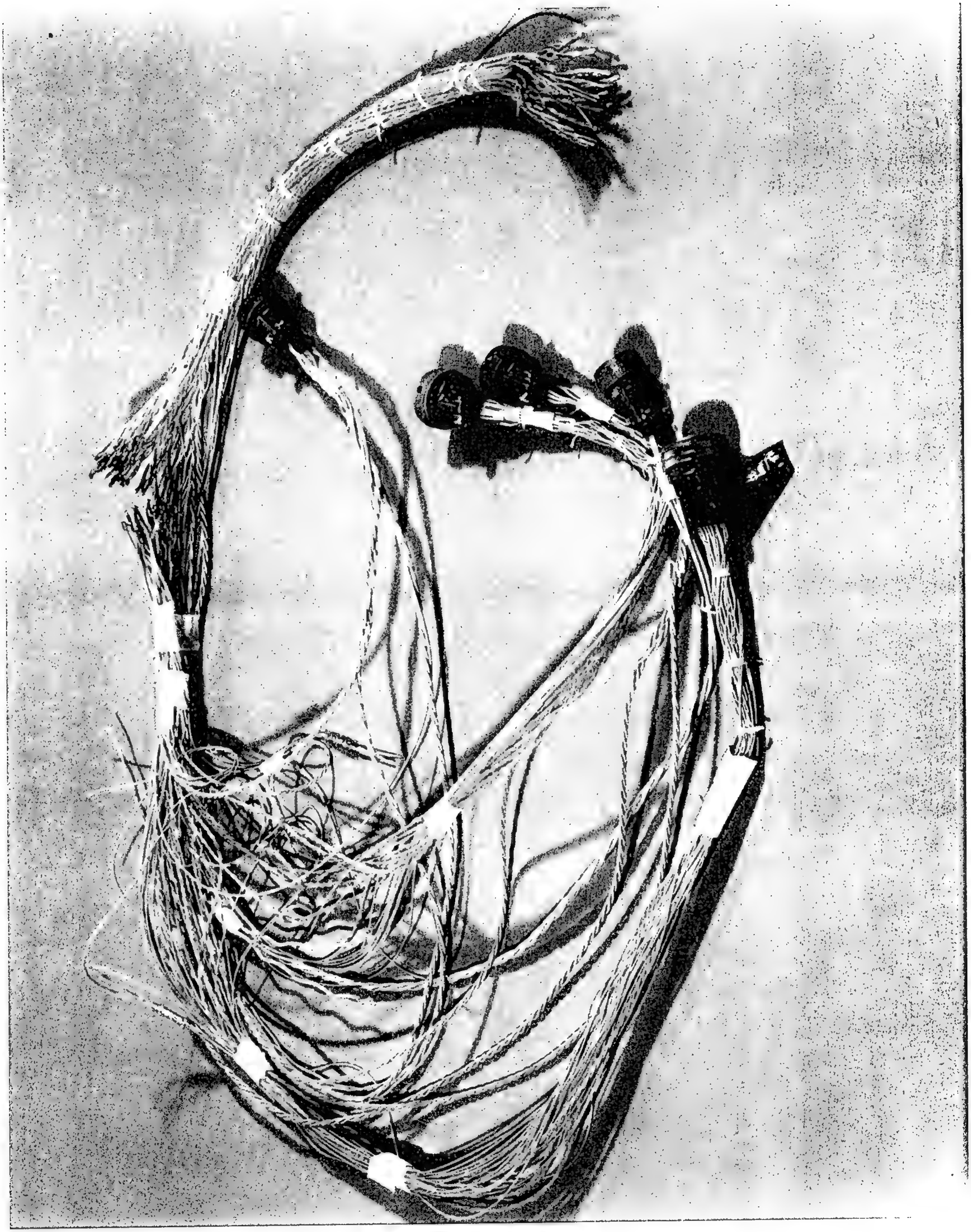
The broad application of tactical mission simulation (TMS) is evidenced by the requests for the tactical air control software (TACS) by industry (Hughes Aircraft, General Electric, etc.) and government (National Air Intelligence Center, ASC/XR and Survivability Information and Analysis Center (SURVIAC)). TMS provides the additional aircraft simulation needed to flush-out an air combat scenario using manned combat stations (MCS) and TACS generated aircraft at a fraction of the cost (only 1% as much) of multiple dome simulators.

Accomplishment

The Simulation Programs Group of the Flight Dynamics Directorate has successfully developed a cost effective method to perform multi-aircraft, real-time tactical mission simulations. Previously, prohibitively high costs for high fidelity simulators had forced simulation facilities to use less than adequate techniques to simulate complex air battles.

Background

TMS is an air combat simulation environment for research and development of new air vehicle technologies, especially control systems, weapons, sensors and integrated vehicle management systems. TMS consists of the TACS package and simulation hardware components such as MCS and the Air Combat suite. TMS brings together high-fidelity air combat simulators, such as the Mission Simulator-1 (MS-1) and Large Amplitude Motion Simulators (LAMARS), with low-cost MCS simulators to permit up to six pilots to participate in mock air battles. Additional players (currently up to twenty) are generated by the computer and are fully integrated into the air combat with weapons, sensors and digital pilot decision logic. By equipping selected simulated aircraft with advanced systems under the Air Force study and conducting realistic air combat missions, the tactical payoff of that system can be evaluated. Air combat simulations are used to test mission effectiveness of designs as soon as possible. Until recently they were limited to one vs. one engagements because the cost of multiple domes and visual systems precluded adding realistic numbers of combatants to the scenarios. Even though it is cheaper to "fly" the design in the simulator, they are still high cost items. The problem is how to contain this cost growth of simulation so that it remains a valid and economical tool for testing weapon system designs. The application of TMS solves this basic problem and is an inexpensive, yet highly credible way to provide a realistic force structure for simulation tests of aircraft weapon systems. As a result, it is now possible to conduct valid, affordable mission tests of weapon system designs prior to building expensive aircraft prototypes.



New Aircraft Wire Insulation

Payoff

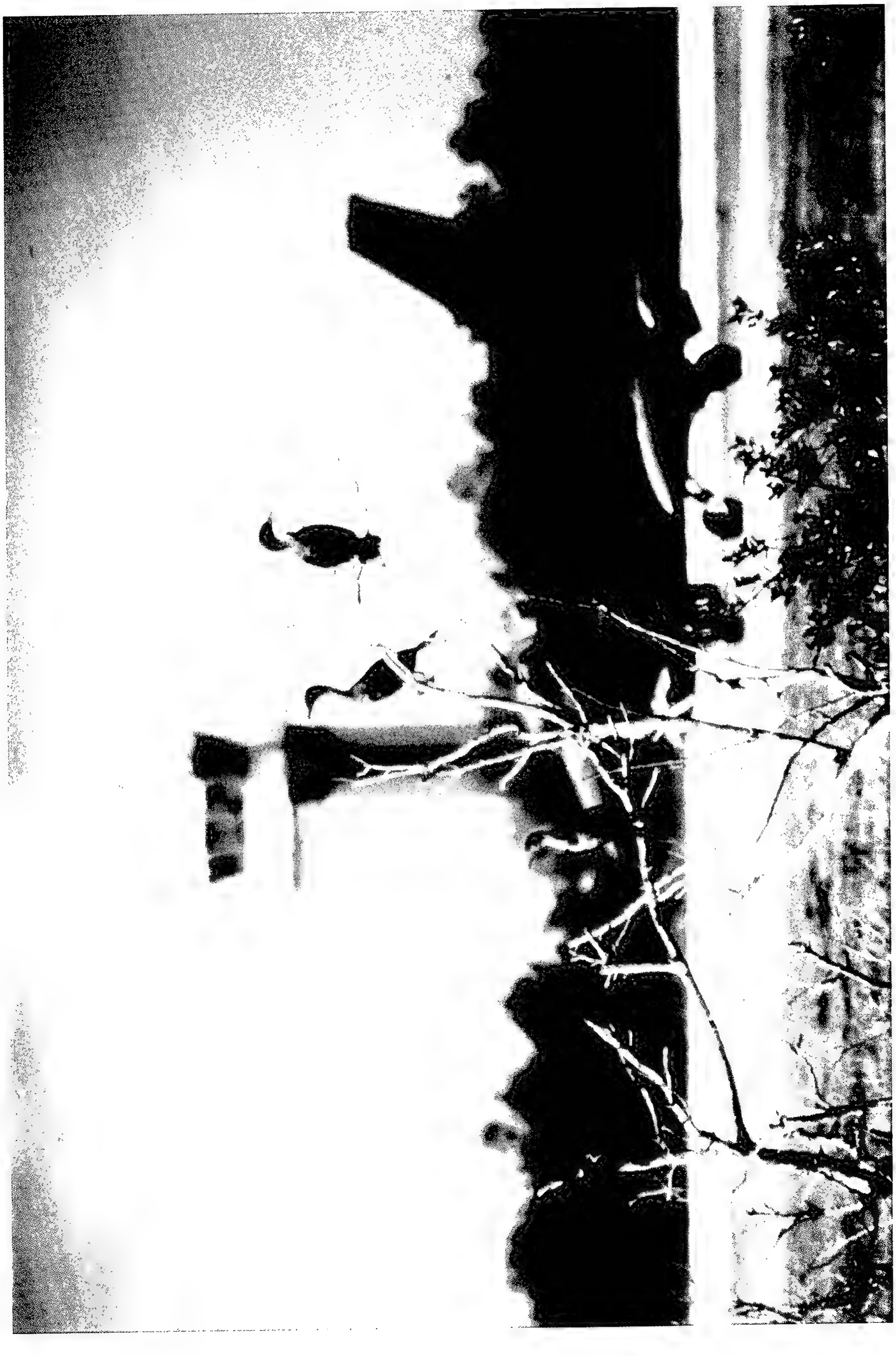
Current insulated wire for aircraft and space vehicles, when exposed, allows flashover (arc tracking) to spread insulation damage increasing the potential for fire. To address this and other insulation problems, Air Force officials have selected and recommended a new insulation technology identified by Wright Laboratory's Materials Directorate. This new approach will increase aircraft wire insulation reliability and reduce maintenance time and costs.

Accomplishment

Specialists from the Materials Directorate's Systems Support Division have identified new materials and methods for insulating electrical wire used in aircraft. Their new approach reduces flashover, increases thermal stability, improves durability and increases wire flexibility.

Background

For the past 20 years, polyimide insulated wire (MIL-W-81381) has been used as the primary wiring for aircraft and space vehicles. Maintenance technicians identified three problems with the polyimide insulted wire. First, if the wire was exposed due to insulation damage, flashover would cause the polyimide insulation to carbonize. As the arcing continued, the insulation damage spread. The results could be a catastrophic fire. Second, they found the wire's long-term exposure to aircraft cleaning fluids and environmental conditions degraded the insulation. Third, they complained the stiffness of polyimide insulated wires complicated repairs in the confined spaces normally found in aircraft. The Materials Directorate conducted field and laboratory investigations to understand failure mechanisms associated with polyimide wiring. Air Force researchers found that various combinations of polyimide and fluoropolymer materials (a hybrid insulation construction) would minimize arc propagation. A hybrid approach also offered more flexibility, higher thermal stability and improved environmental resistance compared to MIL-W-81381 wiring. The manufacture of a hybrid also does not produce ozone depleting materials or hazardous by-products. Using the data gathered in laboratory investigations and meetings with wire users, the Materials Directorate conceived and developed an intense two year effort to identify a wire insulation that would meet anticipated aircraft wiring performance requirements. Air Force researchers and the McDonnell Douglas Aerospace Company developed a cooperative wire insulation evaluation program that involved eighteen aerospace companies and four government agencies. Using statistical analysis and performance oriented testing, the program identified two hybrid wire constructions that had an overall higher performance than polyimide (MIL-W-81381) and the other available aircraft wiring, crosslinked ethylene tetrafluoroethylene (MIL-W-22759/43). At least one of the insulation constructions is commercially available from two sources. Air Force officials are recommending the new insulation for use on all new and replacement aircraft wiring installations and it has been selected for use on the F-22. Engineers at NASA are in the process of certifying the new insulation for space applications and Boeing Aircraft Company has selected it for use on commercial aircraft. The Navy has prepared a new military specification for aerospace wire using the new hybrid insulation technology. The Society of Automotive Engineers (SAE) has issued a new specification for testing aerospace wire based on the new insulation technology.



Ultrasonic Bird Repelling Device Utility

Payoff

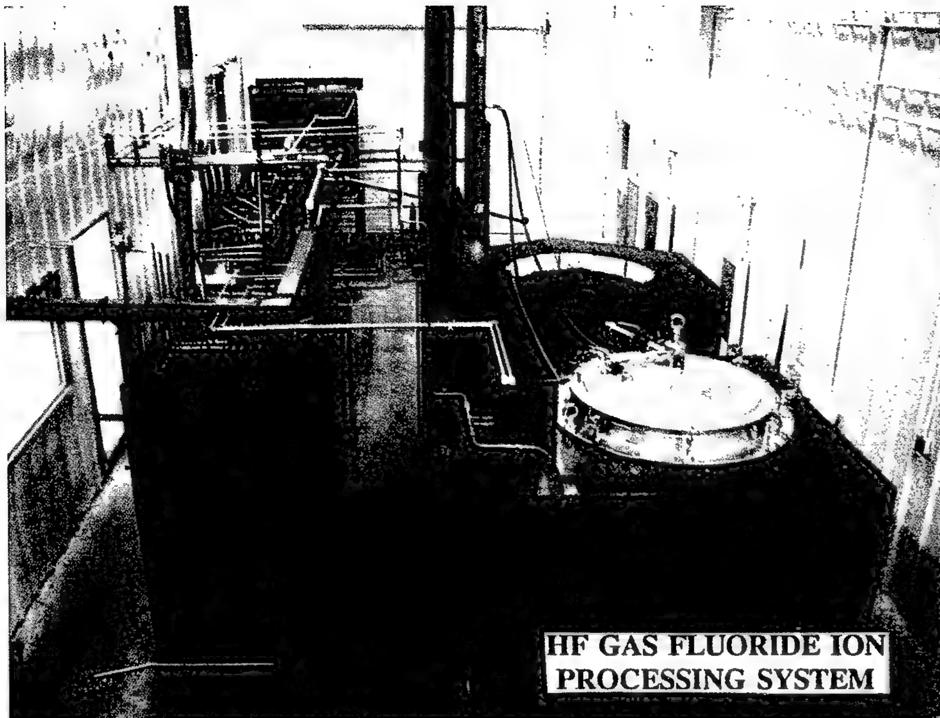
USAF installations will no longer use ultrasonic bird repelling devices (UBRDs) for their bird strike prevention needs. The Flight Dynamics Directorate provided documentation to the USAF Bird/Aircraft Strike Hazard (BASH) Team which shows that UBRDs have little or no effect on bird behaviors around airfields. With the elimination of this device for airfield bird management, an estimated savings of $12.3 million is expected.

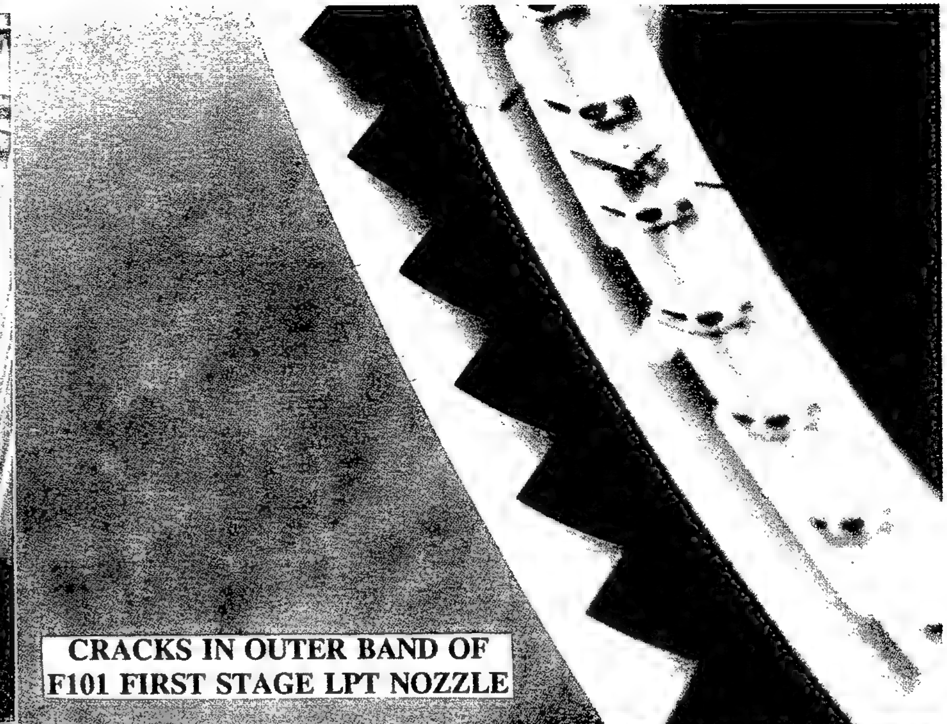
Accomplishment

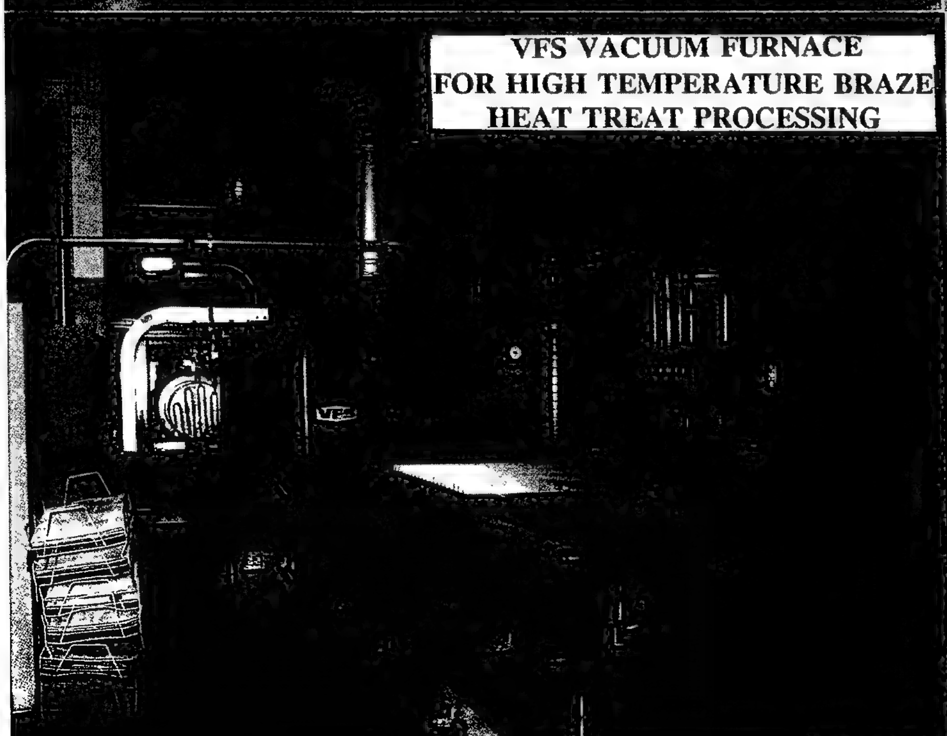
The Flight Dynamics Directorate's Bird Avoidance Program specialists, through their close relationship with the USAF BASH Team, Tyndall AFB have provided documentation to the aircraft bird strike prevention community that UBRDs have little or no effect on bird behavior. The BASH Team, aware that UBRDs were being purchased by USAF installations and that other installations were considering their purchase, needed this information addressing UBRD utility so that they could make valid recommendations.

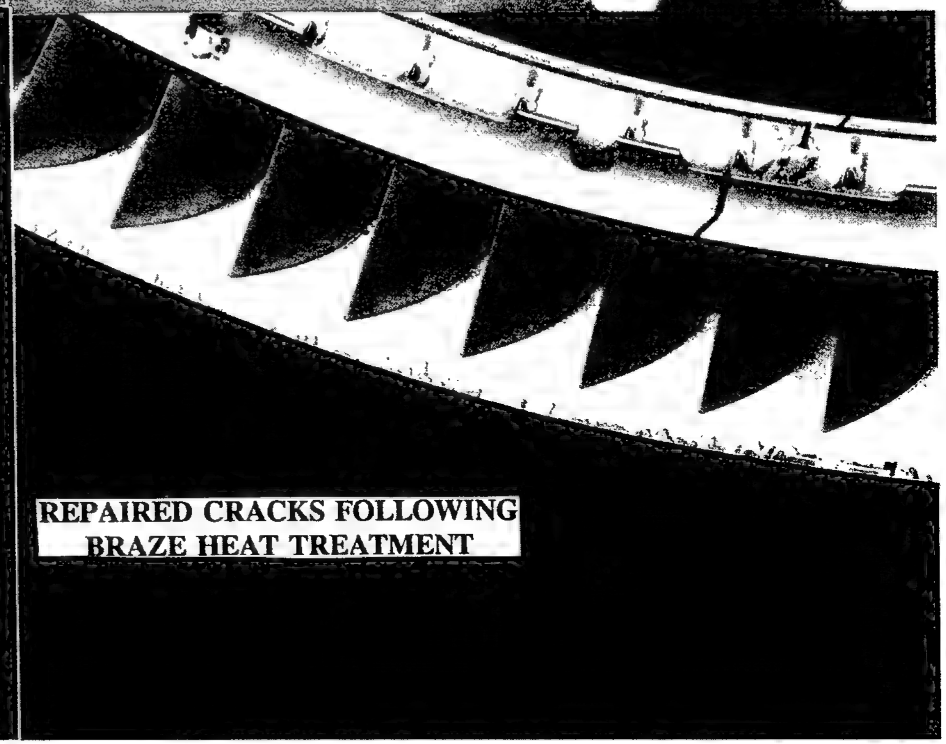
Background

UBRDs have, since the 1950s, been available commercially to their potential users: all branches of the military, airfield managers, biologists, pest controllers, government agencies (the Federal Aviation Administration, the United States Department of Agriculture), agri/aquacuturalists, aircraft manufacturers and homeowners. However, only within the last five years have extensive investigations been accomplished to provide proof for utility. The BASH Team instructs USAF airfield managers and flight safety personnel on the use of the proven methods for reduction of bird populations from the airfield environment. The Bird Avoidance Program recognized the need and potential payoffs for an investigation documenting UBRD performance. The investigation was documented in TR #92-3003 "Ultrasonics as a Method of Bird Control." Advocated by scientists of the aircraft bird strike prevention community as long overdue, this report is unique in that it includes summaries of experiments addressing UBRD effects, bird hearing capabilities and ultrasonic effects on biological systems. Following the presentation of the report at the 21st meeting of the Bird Strike Committee Europe (BSCE) during March 1992 in Jerusalem, Israel, it was recognized as an action item by the BSCE Aerodrome Working Group for distribution to potential users of UBRDs worldwide.


HF GAS FLUORIDE ION PROCESSING SYSTEM


CRACKS IN OUTER BAND OF F101 FIRST STAGE LPT NOZZLE


VFS VACUUM FURNACE FOR HIGH TEMPERATURE BRAZE HEAT TREAT PROCESSING


REPAIRED CRACKS FOLLOWING BRAZE HEAT TREATMENT

Advanced Repair Techniques for Static Jet Engine Components

Payoff

Implementation of hydrogen fluoride (HF) ion cleaning, high temperature diffusion brazing and high-velocity oxy-fuel (HVOF) thermal spray technology at Oklahoma City-Air Logistics Center (OC-ALC) provided a new capability for repair of static jet engine components that will save the Air Force approximately $16 million annually. Requirements for depot maintenance and repair of components, such as cracked turbine nozzles, which are expensive and have no previous qualified repair procedure will be reduced significantly.

Accomplishment

Advanced repair techniques, developed under the sponsorship of the Manufacturing Technology Directorate, for static jet engine components have been implemented in the Process Engineering Division of the Propulsion Production Directorate at OC-ALC. These techniques implemented for the F101, F110, TF30, TF33 and J79 engines provides OC-ALC with new capabilities that will improve the performance of repaired components and enable repair of components which previously had no qualified repair procedure.

Background

Many components in the turbine section of a jet engine, such as Ni-Cr-Co superalloy nozzles, operate at very high temperatures and pressures. As a result, thermal fatigue cracks appear in these components which grow and cause severe engine damage or failure. Until recently, this form of damage was repaired using conventional gas tungsten arc welding (GTAW). However, this technique is complicated by the poor weldability of the Ni-Cr-Co superalloys. As a result, GTAW repair of cracks in turbine nozzles has not been implemented at OC-ALC and cracked nozzles are either scrapped or stored, awaiting new processes for repair. Under the Manufacturing Technology Directorate's Static and Accessory Repair Program, a new method of repairing cracks in nozzles has been developed. Cracks in superalloy components can now be repaired by high temperature diffusion brazing. This method repairs cracks and restores the mechanical properties to near base metal levels. The first step in the brazing repair process is cleaning of the component. The HF ion cleaning (HFIC) process is a cost effective method of preparing nickel and cobalt based superalloys for braze repairs. Following component cleaning, a specialized braze alloy is selected to closely match base metal composition and is applied to cracks with the use of pneumatic hypodermic applicators. Heat treatment of the component is performed in the vacuum brazing furnace at temperatures sufficient to melt the braze alloy, and in high vacuum (5×10^4 torr) to avoid contamination of the repair joint. Wear of engine hardware is another common cause for repair and requires restoration by thermal spray processes, welding or plating. Conventional thermal spray processes are less prone to distortion and cracking, but produce coatings with performance characteristics limited by relatively low bond strength and density. The HVOF thermal spray process developed by the Manufacturing Technology Directorate produces coatings that exhibit superior properties relative to coatings produced by conventional thermal spray processes and are excellent replacement coatings for chemical plating or weld processes.

Air Force Materials Processing Research Saves $500,000

Payoff

Researchers in the Materials Directorate tested a specially shaped die technique in a 700-ton extrusion press. Providing materials processing research assistance to the Extrusion Technology Company of America by matching commercial extrusion needs and Air Force research results saved their customer, the Department of Energy, $500,000 and could improve the way extrusion companies process refractory metal alloys that will be rolled into sheet for the final application.

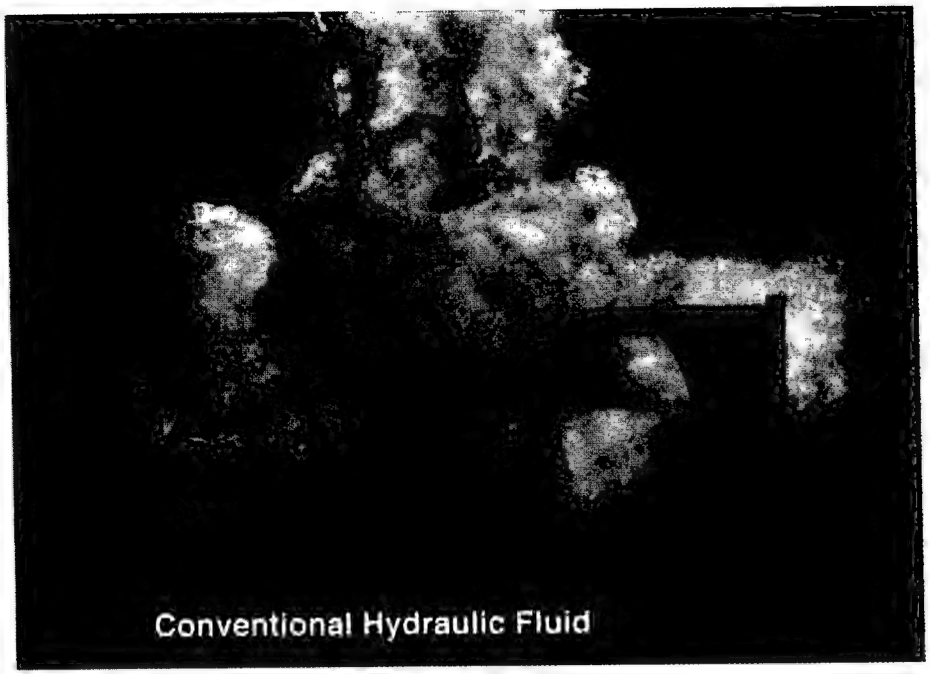
Accomplishment

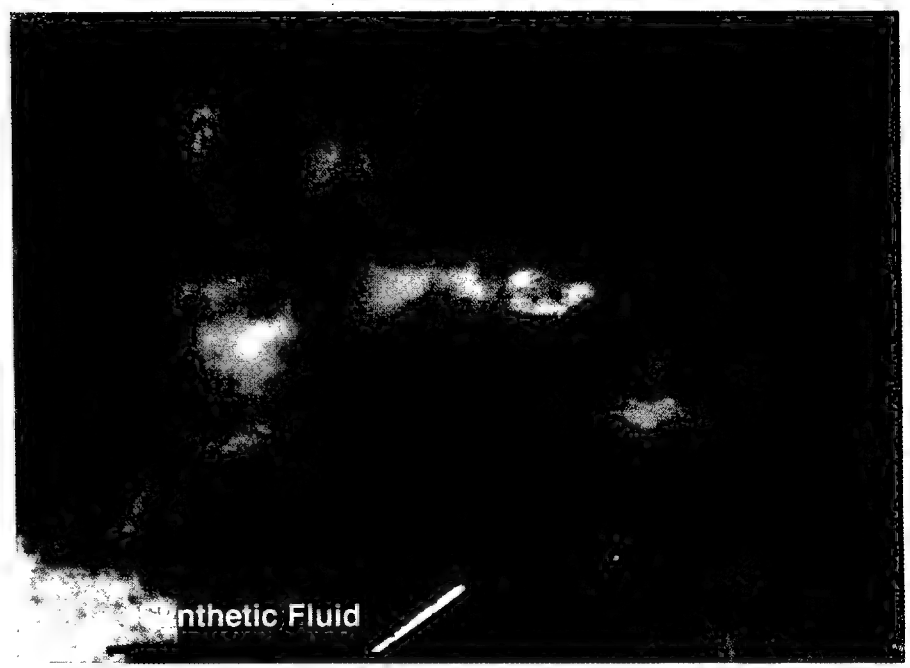
Scientists, working in the Materials Directorate, developed a process for extrusion of refractory metal alloys. One recent application of this process saved the Department of Energy $500,000 and will speed up the production process for extruding metal alloy bars.

Background

The Department of Energy needed large rectangular bars of a tantalum-hafnium-molybdenum refractory metal alloy (T-22) for rolling into sheet as part of a special project. Extrusion Technology Company of America, the vendor for the metal alloy bars, felt that a direct extrusion to sheet bar could eliminate a forging operation and increase the yield of the final rolled product. They proposed using the same extrusion technique used for titanium extrusions. Their consultants at Refractory Metals Technology advised them that materials processing research by scientists in the Materials Directorate had shown that the processing techniques used to make one material often failed when applied to process another material. Researchers in the Directorate's Experimental Materials Processing Laboratory were asked to help find the best way to extrude the required metal. They tested the vendor's proposed shear die technique which failed to produce an acceptable extrusion. Based on years of process modeling experience, engineers in the Materials Directorate recommended using a specially shaped die. A test of the revised die design proved the extrusion process worked. The Extrusion Technology Company of America will use the process to extrude the alloy bars.

GUNFIRE IGNITION TEST





New Hydraulic Fluid Increases Pilot Safety

Payoff

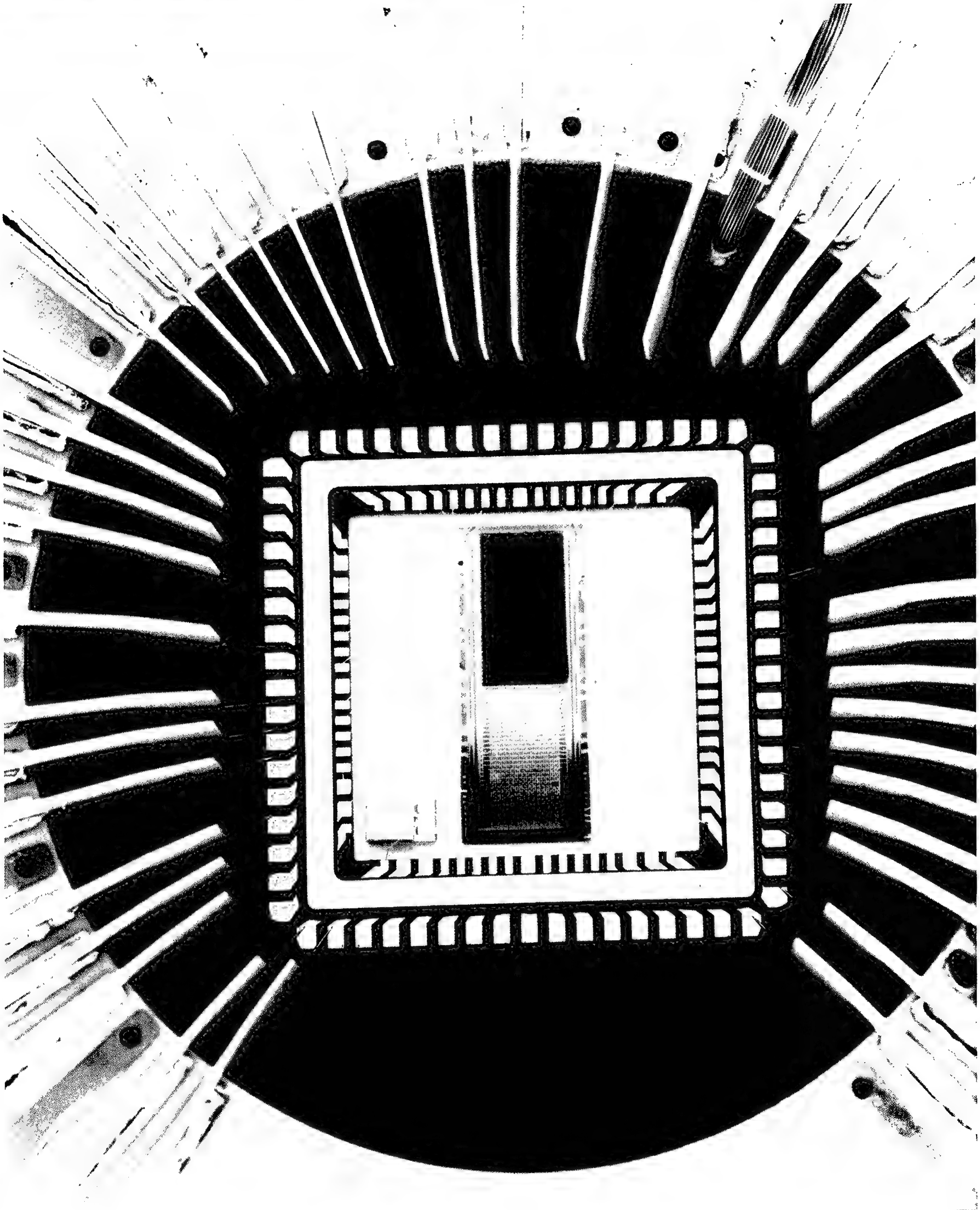
Using this new hydraulic fluid will substantially reduce aircraft fires while allowing aircraft to meet the extremes of operational temperatures. When Air Combat Command's fleet has been fully converted to the new fluid, an estimated savings of $25 million per year could be realized due to reduced aircraft damage losses and lowered life-cycle costs. The improved fire resistance of the new MIL-H-87257 hydraulic fluid, in comparison to the traditional petroleum-based fluid, is depicted left. The traditional fluid when impacted by a .50 caliber incendiary projectile exploded in a ball of fire, while the new fluid resisted explosion and fire.

Accomplishment

The Materials Directorate has developed a new type of fire resistant hydraulic fluid that will allow safer operation of aircraft over the temperature range of -65°F to +275°F. This MIL-H-87257 hydraulic fluid lowers the temperature that aircraft can operate using fire resistant hydraulic fluid from -40°F to -65°F.

Background

Ever since hydraulic fluid was introduced for use in aircraft it has caused or facilitated a number of catastrophic aircraft fires. Petroleum-based hydraulic fluid was capable of operating at temperatures down to -65°F but was quite flammable. During the mid-1970s, Materials Directorate scientists developed a fire resistant hydraulic fluid based on a synthetic hydrocarbon polyalphaolefin that reduced the incidence of fire. This MIL-H-83282 fluid, capable of operating at temperatures in the range of -40°F to +275°F, was adopted for use by many Air Force and Navy aircraft, Army land systems and NASA's space shuttle. However, since B-52 and B-1 bombers required the capability to operate at -65°F, use of the older, more flammable petroleum based fluid presented a potential hazard to these aircraft. Recently scientists in the Materials Directorate's Nonstructural Materials Branch developed a new type of fire resistant hydraulic fluid. With a flash point above 300°F, this MIL-H-87257 fluid will allow aircraft to operate in temperatures as low as -65°F and as high as +275°F with reduced incidence of fire. This new fluid, based on a different synthetic hydrocarbon polyalphaolefin and a modified additive package, is compatible with existing aircraft hydraulic system components. It is interchangeable with the older fluids on a drain-and-refill basis and offers the potential for having a single, common hydraulic fluid for all Air Force aircraft. It has been tested by Rockwell International on a B-1 simulator with very positive results. Additional testing is being conducted to support transition into the Air Combat Command's fleet. The new fluid is also fully compatible with commercial hydraulic systems that use oil based fluids, such as those used in general aviation aircraft, farm and earth moving equipment, forging and extrusion presses, molding machinery and die cast equipment.



New Manufacturing Processes for Infrared Detector Arrays

Payoff

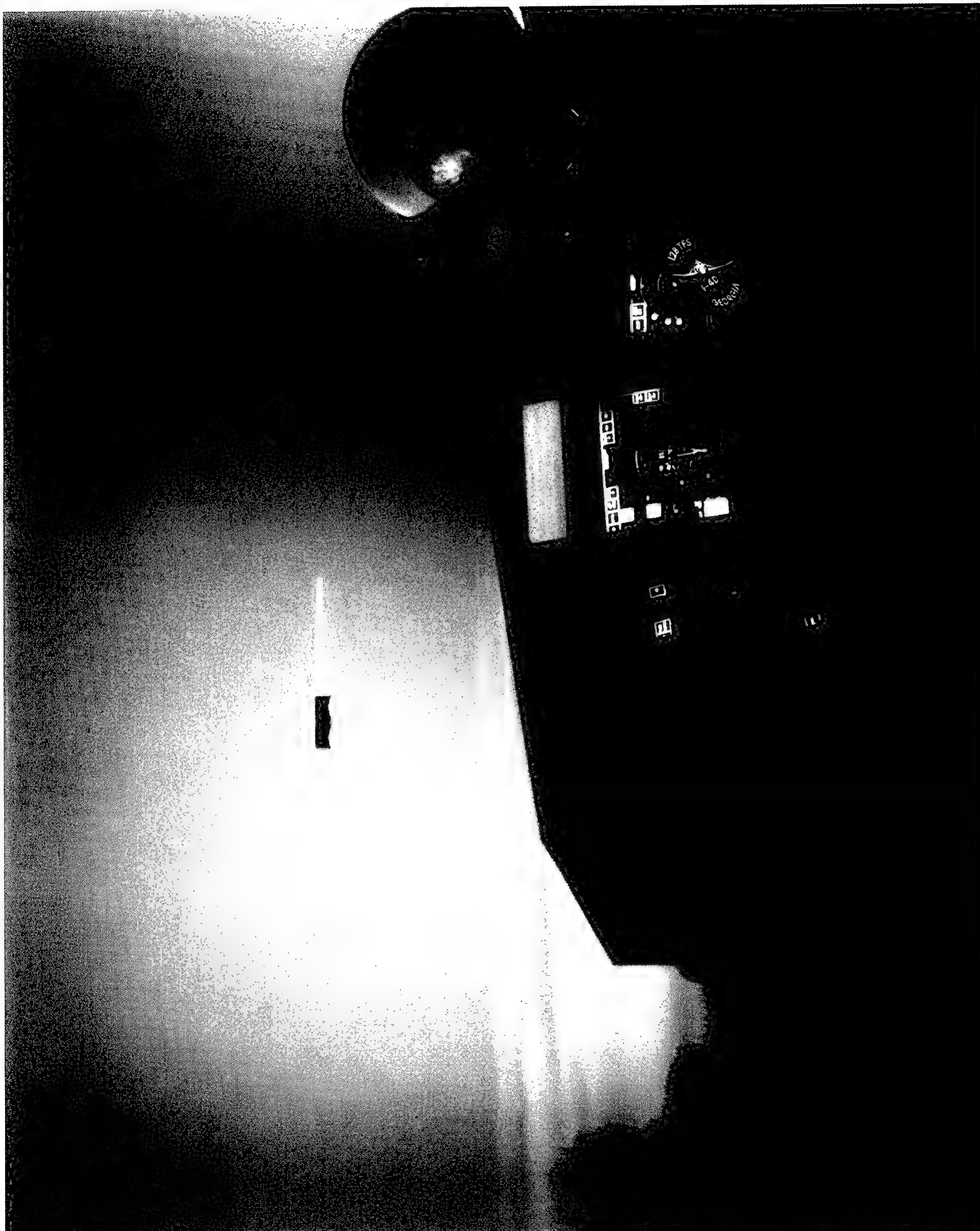
Reducing the production cost of infrared detector arrays (such as the one shown left on a sensor chip test assembly made from mercury cadmium telluride) by as much as a factor of 14 has eliminated detectors as the cost driver in sensors for surveillance, missile guidance and night observation systems. Array yield improved from 3.5 to 51 percent and costs were reduced from $60,000 to $3,200 per array.

Accomplishment

Research sponsored by the Manufacturing Technology (MANTECH) Directorate has significantly lowered the cost of strategic and tactical sensors by efficiently producing mercury cadmium telluride infrared detector arrays. The cost of a hybridized detector array has been reduced by a factor of 20, array yield has been increased by a factor of 14, and production of acceptable pixels has increased by a factor of 30.

Background

Current and future wartime scenarios make infrared detector arrays vital to the Department of Defense. These arrays are used in sensors for surveillance, missile guidance and night observation systems. Research has shown that one of the most promising materials for producing these arrays is mercury cadmium telluride, but its high cost made it impractical. To make affordable mid-wave infrared detector arrays, MANTECH initiated separate programs with Hughes Santa Barbara Research Center (SBRC) and Rockwell International's Electro Optical Center Division to develop improved manufacturing processes. Goals for both programs were established to enhance the basic technology by reducing the hybridized detector array cost by a factor of 10 to 20 and demonstrate a 2 to 20 million pixel per year production capacity. Both contractors established a baseline to measure their programs. Each production run provided an assessment of the contractor's yield, cost and throughput and identified the fabrication process steps. After evaluating the results of the initial production run, each contractor went on to perform intermediate and pilot production runs. Each production run involved material growth, processing material into infrared detector arrays and testing the arrays with a transparent readout device. Both contractors reported significant manufacturing improvements.


128 TFS
F-4D

Pilot's Associate Program

Payoff

The Pilot's Associate Program concluded over 6 years of research with a real-time, manned, air combat demonstration of the Pilot's Associate's fighter. The capabilities of the Pilot's Associate's knowledge based systems frees the pilot to do more productive tasks, enhance his situational awareness, and increase mission effectiveness and survivability. This exciting technology has been inserted into the F-22 and is being evaluated for the Joint Advanced Strike Technology fighter program and varied systems such as highway and air traffic management, commercial airlines, unmanned air, sea, and land vehicles and autonomous satellite operations.

Accomplishment

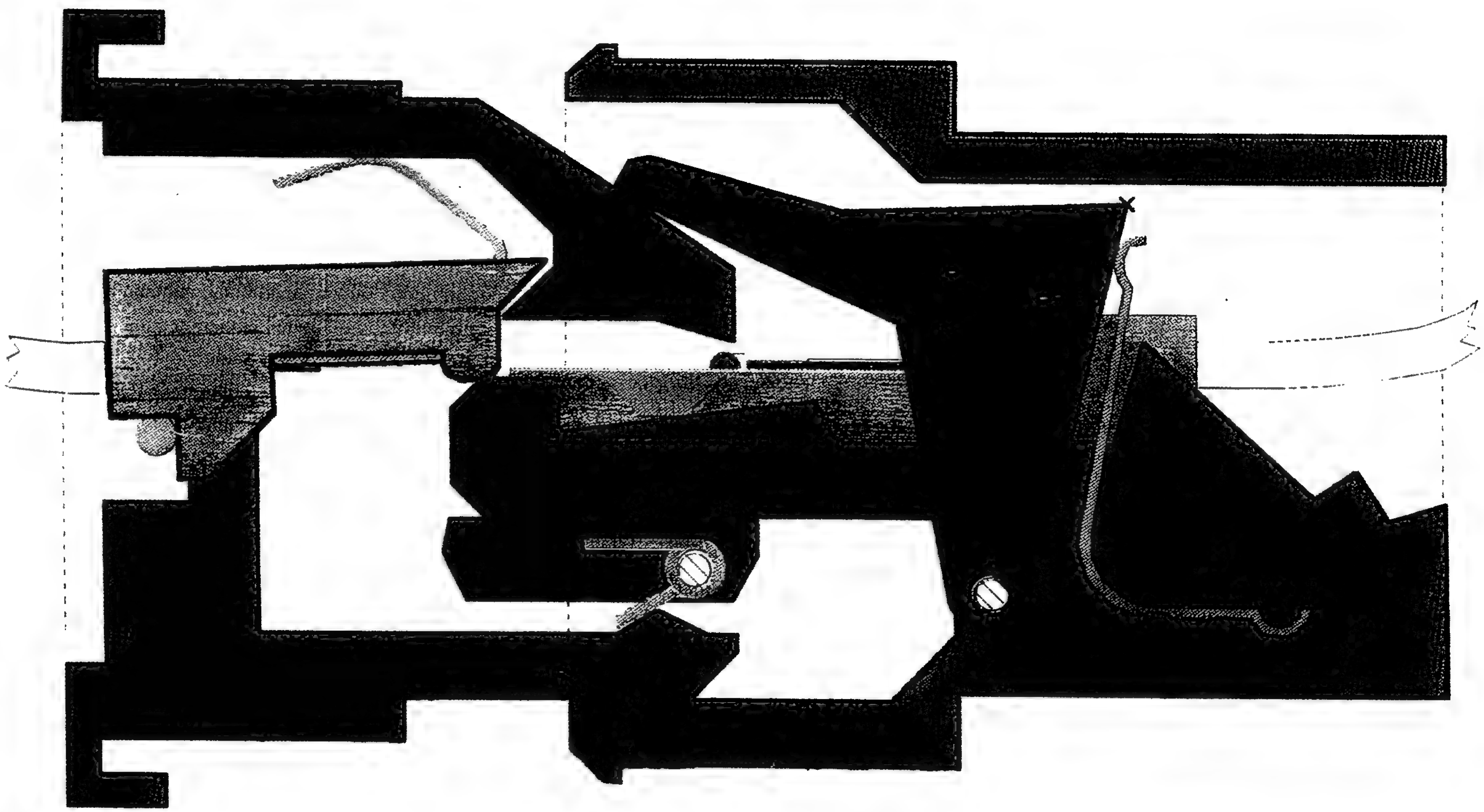
The Pilot's Associate Program managed by the Flight Dynamics Directorate has achieved its objective of combining the benefits of artificial intelligence with conventional avionics software to create an intuitive, information rich and manageable cockpit for the pilot of the next generation of single-seat fighters. This internationally recognized program, funded by the Advanced Research Projects Agency (ARPA) has been responsible for many notable achievements in computer science and cockpit technology.

Background

The Pilot's Associate program applied artificial intelligence methods to solve the fighter pilot's ever expanding workload in managing complex systems. Effective management of this information explosion from multiple sources helps gain and maintain situation awareness and aid in decision making in an ever changing wartime environment. Pilot's Associate defined a new field of intelligent systems with a concept and architecture for the integration of multiple, cooperating, knowledge-based systems. The final phase of the program transitioned that architecture from the laboratory environment to a real-time avionics processing environment. The program also developed innovative system engineering methods to cope with the complexities of a software project developed with rapid prototyping and new software methods in object-oriented design. The electronic Pilot's Associate aids the pilot in the areas of mission planning, system status, tactics planning, situational assessments and intelligent display manipulation through the use of five cooperating knowledge bases. Technology demonstrations for a special operations transport aircraft, and the F-16 and F/A-18 fighters have been performed. The most ambitious efforts to date employing technologies pioneered in the Pilot's Associate Program involve the Army's Rotocraft Pilot's Associate Program, where an intelligent system will be developed and flight tested for the single-seat combat helicopter pilot, and the Army Tank Crew Associate Program, where an intelligent system will be developed, inserted and tested for the two-crew main battle tank.

ROC Connector

(Cross-section of a Partially Mated Pair)



0.5 Inches

Reliable Optical Card-Edge Connector (ROC)

Payoff

The reliable optical card-edge connector (ROC) will enable the use of highly reliable fiber optic data transfer networks resulting in increased weapon systems performance and availability. Combat capability will be enhanced through more robust and high performance communication links. Fewer system failures will require less maintenance and repair actions, which will reduce weapon system life cycle costs. The ROC is being fitted into the Bendix line replaceable module connector which is the module connector of choice for the F-22.

Accomplishment

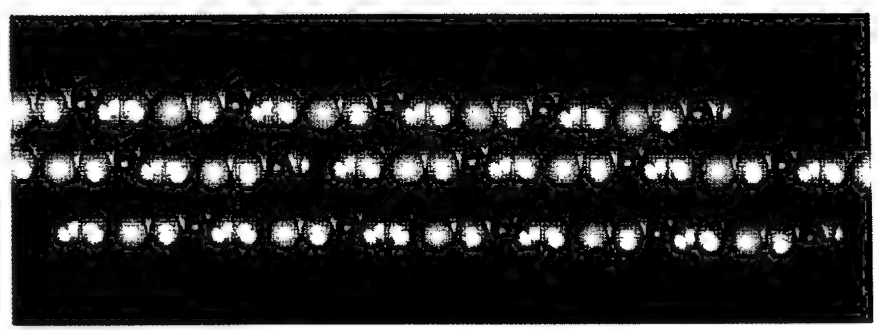
The Wright Laboratory's Avionics Directorate has developed a new low cost optical connector that employs expanded beam optics and micromachined silicon alignment blocks to maintain extremely accurate alignment, even under severe shock and vibration conditions. This ROC also provides self-sealing doors that protect the unmated connectors from sand, dust and abusive handling.

Background

Advanced weapon systems depend on rapid and reliable data transfer. Fiber optic networks have long been touted for their high bandwidth and excellent noise immunity. However, efforts to introduce photonic networks into avionics systems have been less than successful due to design, reliability and maintainability problems. Many of these problems have been traced to particulate contamination and failure under severe environmental conditions. Since the F-22, Boeing/Sikorsky's Reconnaissance Attack Helicopter (RAH-66) and several commercial aircraft are planning to use photonic networks, there has been considerable effort underway to develop more reliable connectors and components. A particularly failure-prone component has been the blind-mate connector that provides the optical interface between a line replaceable module (LRM) and the backplane. Upon insertion, this connector must align the axes of the module and backplane fibers to within one ten-thousandths of an inch. Furthermore, it must preserve this critical alignment under extreme thermal, mechanical and chemical stresses. Most of the blindmate connectors to date use a butt-coupled approach with spring-loaded ferrules providing alignment. These connectors have been susceptible to failures induced by vibration, dust and dirt, and salt fog. The Avionics Directorate has responded to this user community need by developing a new type of optical connector. The ROC has been integrated with several LRM electrical connectors. It was initially designed and tested for the Teradyne connector and was subjected to the same test conditions that the Joint Integrated Avionics Working Group (JIAWG) used to test the existing optical connectors. Whereas the existing connectors failed all or most of these tests, the ROC was able to pass all the tests, except for the salt spray test. A minor redesign on the self-sealing doors has eliminated this problem. The ROC has been redesigned to fit into the Bendix LRM connector, which is the module connector of choice for the F-22. Initial discussions have occurred with members of the RAH-66 Comanche team, as they have expressed interest in using the ROC to solve their optical interconnect problems.

ORDERED ROD-LIKE
POLYMER STRUCTURE

CONVENTIONAL
POLYMER STRUCTURE



COMPUTER GENERATED ROD-LIKE
POLYMER SCHEMATIC

Rigid Rod Polymer Technology Transfer

Payoff

Shown on the left is a comparison of rigid rod and conventional polymer structures. Also depicted is a schematic representation of ordered, rigid rod polymer molecules. Transfer of the new rigid rod polymer technology allows commercial manufacturers to use lightweight, stiff, high strength composites for many applications including those requiring electrical insulating material. Some possible military uses for the material includes aircraft skin and radomes (antenna covers).

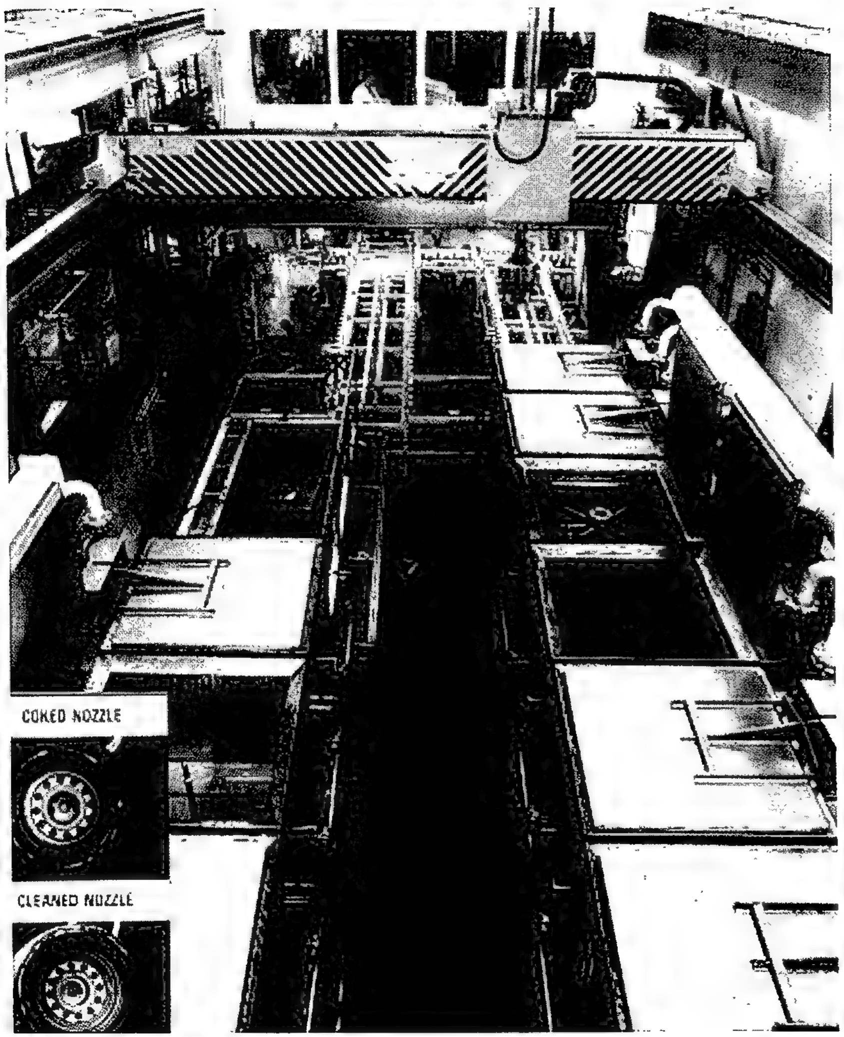
Accomplishment

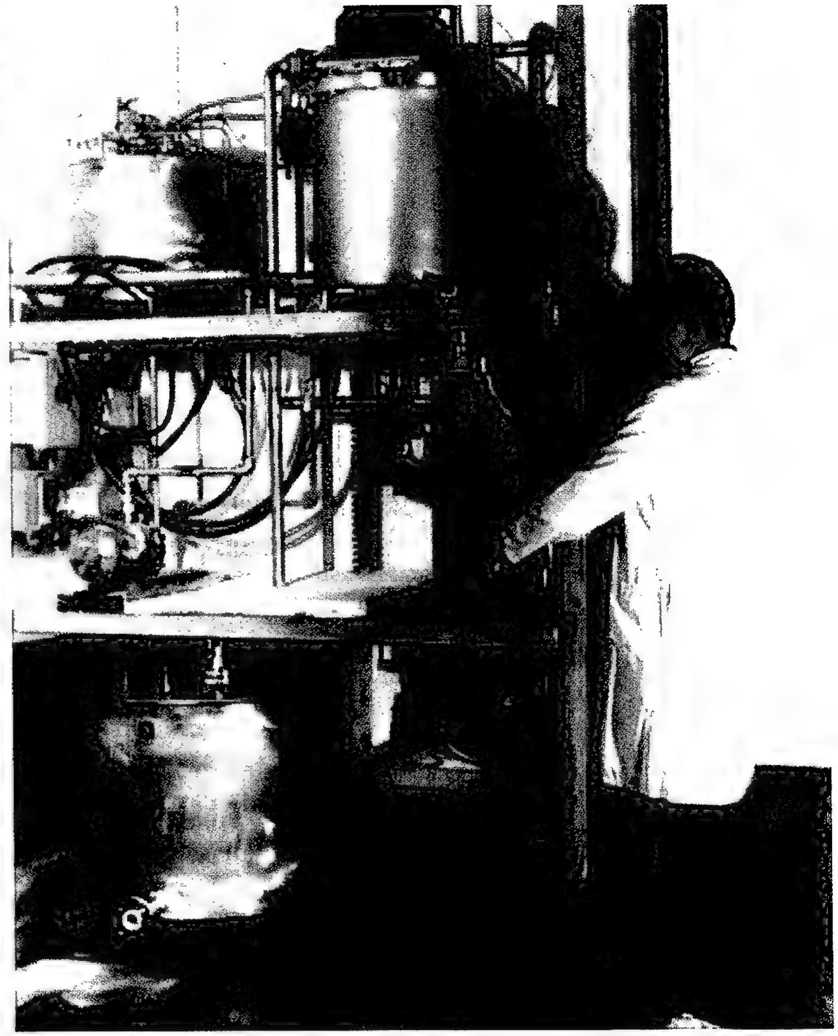
Materials Directorate scientists have developed a stiff, electrical insulating, polymeric material that is 10 times stronger than an equivalent weight of steel and can operate at temperatures above the softening point of aluminum. This synthetic polymer can readily be fabricated as films and fibers and enables the manufacture of stiffer, stronger electrical insulating composite components. Dow Chemical Company of Midland, MI, has acquired rights to the technology and plans to market the material for both commercial and Department of Defense (DOD) applications.

Background

Composite materials for varied DOD and civilian applications have become almost commonplace. Many of these composites, because of the need for stiffness, are produced with materials that conduct electricity. Because of their electrical conductive properties, these composites cannot be used for components that must operate without electrical interference. Composite materials commonly used for components requiring electrical insulation usually lack strength, stiffness and thermal stability. Researchers in the Materials Directorate have developed new materials that exhibit strong resistance to being pulled apart (high tensile strength) and are stiff and resist bending (high modulus of elasticity). These materials have good high temperature thermal stability and are also electrical insulators. The unique properties exhibited by these materials result from their molecular structure.

In conventional polymer materials, such as those used in plastics and fabrics, the chains of molecules exist as twisting, intertwined structures at the molecular level. The new stiff, nonconducting materials are synthetic polymers (groups of molecules connected to form a repeating structure or chain) and the chains have the microscopic appearance of straight rods. These rods can be aligned in the material so that they are parallel to each other making the resulting material stiffer. After these rod-like polymer materials were synthesized in the Materials Directorate's in-house laboratories, the Directorate contracted with SRI International, Menlo Park, CA, to further refine the processing technology. Dow Chemical Company has acquired rights to the technology and is making a multimillion dollar investment to exploit it for commercialization.


COKED NOZZLE
CLEANED NOZZLE



Robotic Engine Manifold Cleaning Cell (REMCC)

Payoff

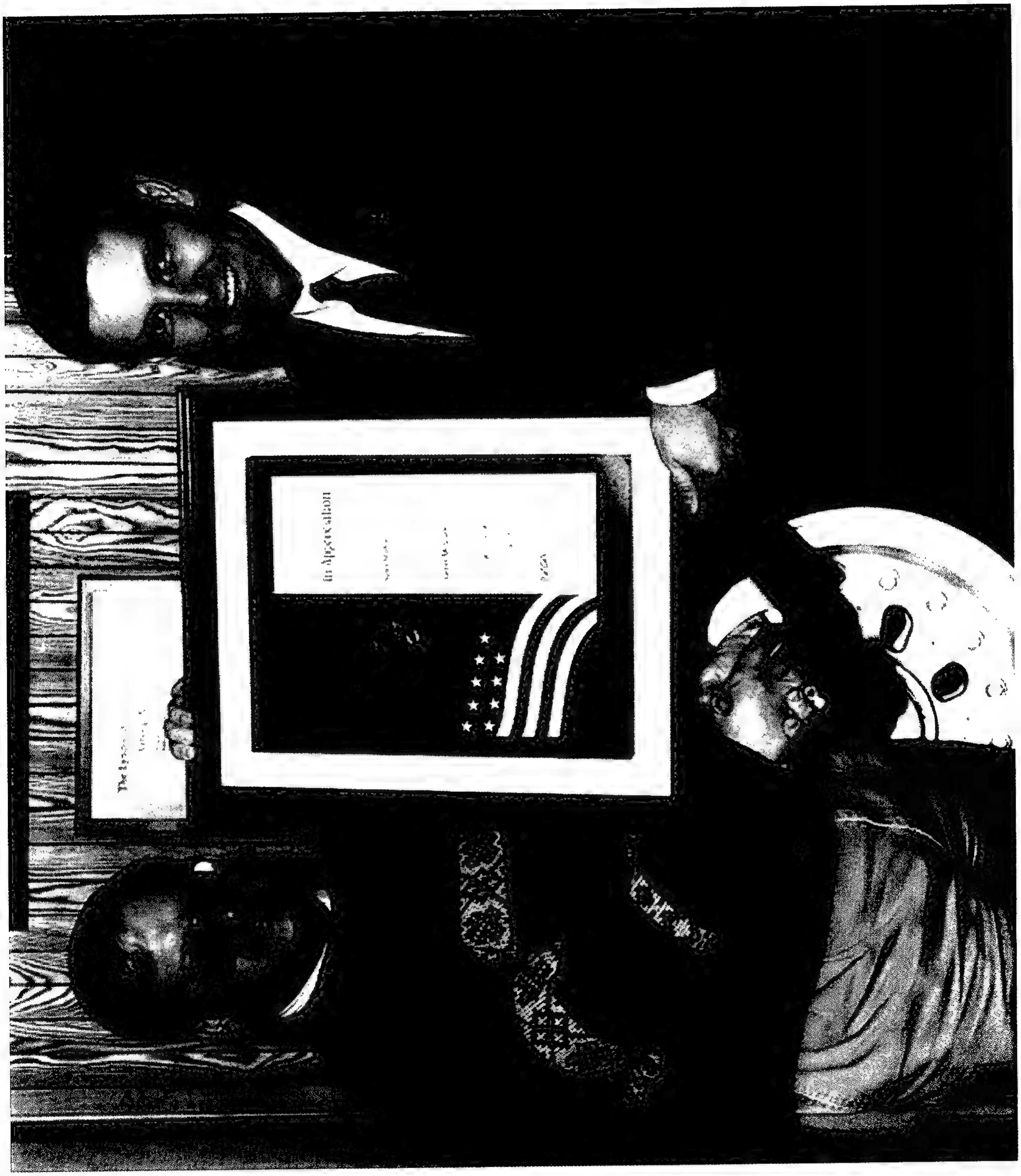
The functions of the robotic engine manifold cleaning cell (REMCC) (shown far left) are designed to remedy all of the shortcomings of the previously used process at Oklahoma City-Air Logistics Center (OC-ALC) and save the Air Force $1 million per year. The chemical (permanganate) rejuvenation system (shown near left) is an integral part of the REMCC and will reduce process material costs by 95%. The REMCC will accommodate full manifold components from the F110, F101, F108, TF30, TF33 and J79 engines, as well as future workload engines such as the F119.

Accomplishment

The Manufacturing Technology Directorate's automated REMCC and chemical solution rejuvenation system successfully completed validation testing at General Atomics in San Diego and has replaced all hazardous manual operations currently performed in the OC-ALC Accessories Division engine manifold cleaning shop. The cell's chemical rejuvenation system eliminates 100% of the hazardous waste and prevents cleaning solution deterioration and sludge buildup.

Background

An important part of aircraft maintenance is the removal of carbon (or "coke") deposits from engine-manifold parts which build up and restrict fuel flow into the combustion chamber, severely affecting engine performance and efficiency. In some instances, deposits can break loose during engine operation, causing valve seats to jam open, resulting in "burn outs" of the engine, with very severe consequences. The manifold parts are cleaned to remove the accumulated coke deposits using chemical oxidation with a hot (190°F) concentrated solution of potassium permanganate and sodium hydroxide pumped through the parts. Over the years, this cleaning method has evolved into a large-scale activity at OC-ALC, but the fundamental "hands-on" operating techniques have remained the same. These manual techniques involve loading of uncleaned parts into fixtures and containers, insertion into tanks of hot cleaning solution, retrieval from the tanks, rinsing, drying and inspection. In addition, the current process cleaning hardware is becoming obsolete in comparison with modern equipment now available. Finally, in the present cleaning system the permanganate solution loses its oxidation potential after a short period of use and generates a solid sludge (manganese dioxide and sodium bicarbonate) after reaction with the coke. This sludge is the direct result of a severe loss in cleaning ability and accumulates in the current system causing pumps to fail, thus reducing production levels and greatly increasing rework and scrap rates. The combined loss in cleaning effectiveness and sludge accumulation makes frequent disposal of the spent potassium permanganate solution necessary, adding to the already burdened Air Force Materiel Command's (AFMC) hazardous waste stream.



Award for Shuttle Orbiter Vehicle Support

Payoff

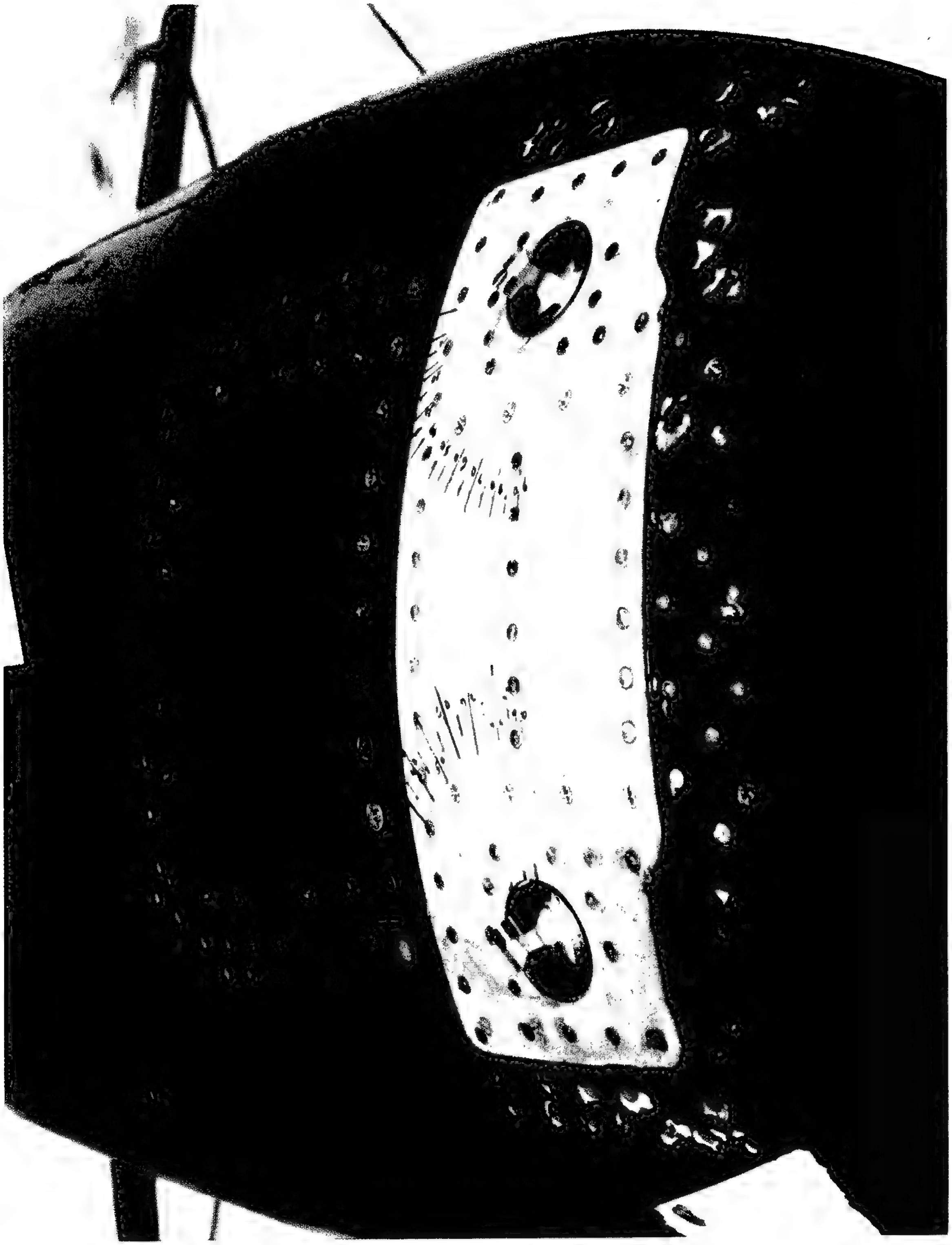
Mr. J. Greer McClain was presented the Silver Snoopy Award by Astronaut Robert Cabana for contributions to flight safety and mission success for the Shuttle Orbiter vehicle. The testing and evaluation of Shuttle Orbiter landing gear components at the Flight Dynamics Directorate's Landing Gear Development Facility has significantly improved the flight safety of the Orbiter vehicle over the entire spectrum of potential landing scenarios.

Accomplishment

Mr. J. Greer McClain of the Flight Dynamics Directorate's Vehicle Subsystems Division received the prestigious Silver Snoopy Award for his contributions to the engineering development and certification testing of improved landing gear wheels, tires and brakes for the Shuttle Orbiter vehicle. The award which recognizes significant contributions to flight safety and mission success of manned space-flight was presented by Astronaut Robert Cabana.

Background

The Vehicle Subsystems Division has supported the Shuttle Orbiter project in three major areas. First, the integrated carbon brake/antiskid/landing gear test program was successfully completed after adding a major modification to the Landing Gear Development Facility's 192 inch dynamometer and conducting a series of dynamic landing and braking test to verify landing gear stability. The test results obtained gave NASA engineers and managers the confidence needed to transition the new carbon/carbon brakes to the flight vehicle. Carbon brakes first flew on the STS-31 mission, and are now standard equipment on all Orbiter vehicles. Second, the Division supports every Orbiter mission by preparing the nose and main gear tires for flight. All Orbiter tires are pre-rolled on a Dynamometer (break-in) and inspected by the Division's state-of-the-art shearographic tire analyzer (non-destructive inspection) before delivery to Kennedy Space Center (KSC) for preflight buildup. Third, the Division has participated in engineering development and certification testing of Orbiter nose tires and main wheels and tires. Most recently, certification testing was successfully completed on the new "commercial tread" main gear tire, which was designed to optimize landing performance on the runway at KSC. The test program succeeded in certifying the main wheel and tire for a "worst case" abort landing at KSC. The new commercial tread tire was first flown successfully on the STS-50 mission, and is now standard equipment on all Orbiter flights.



Vortex Flow Control (VFC)

Payoff

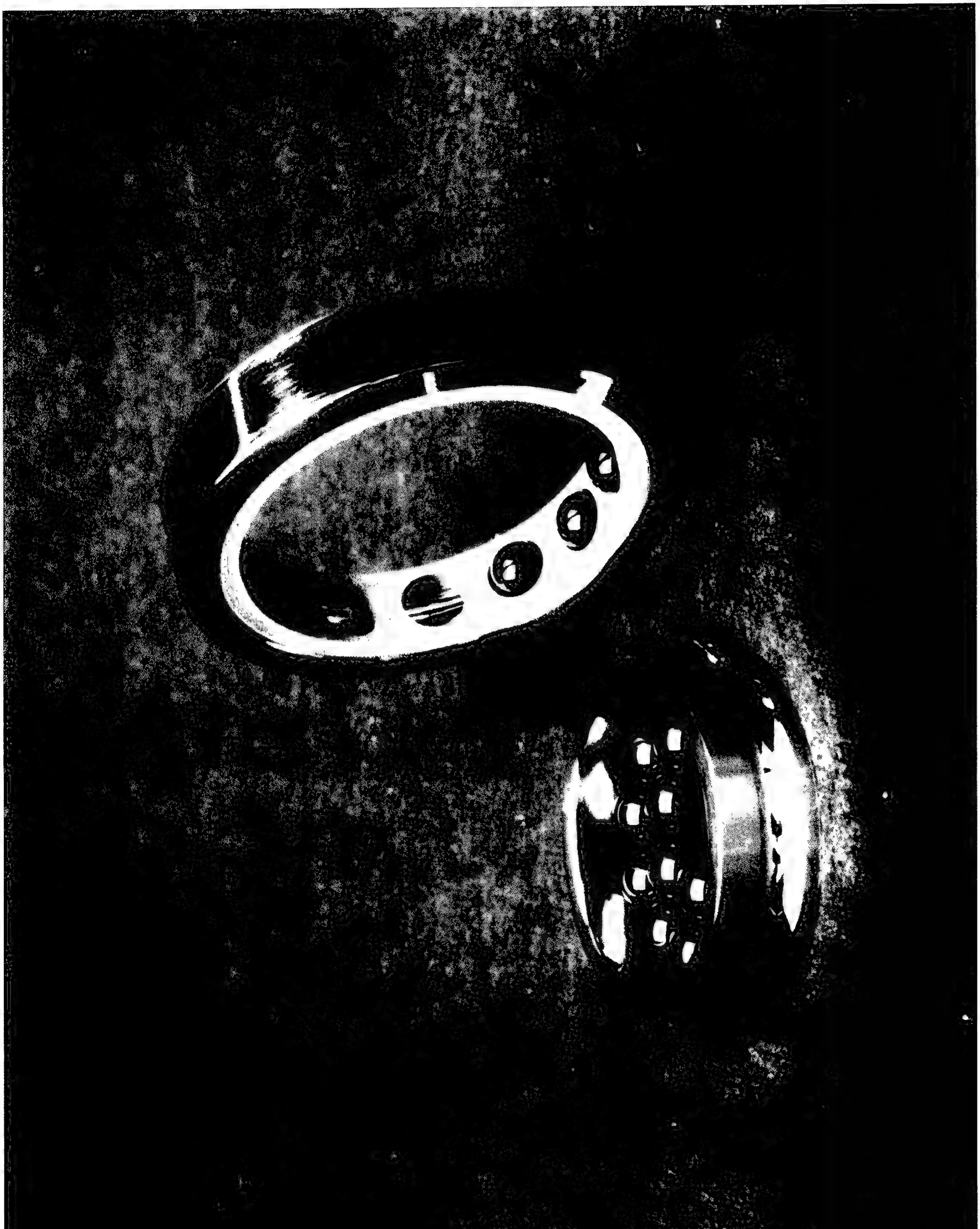
Tests with the X-29 technology demonstrator have proven that vortex flow control (VFC) exceeds available rudder power to control an aircraft at high angle-of-attack (AOA). A close up of the flow control hardware installed on the nose of the X-29 is shown left. This technology provides the aggressive nose pointing needed for close-in combat success and safe flight at high AOA. The Flight Dynamics Directorate plans to put VFC on either the Variable Stability In-Flight Simulator Test Aircraft (VISTA F-16) or the Advanced Fighter Technology Integration F-16 as part of a two year demonstration program.

Accomplishment

The X-29 technology demonstrator has successfully demonstrated yaw control without any rudder input using VFC. The self-contained VFC system has shown to be effective in yaw response up to 52 degrees AOA.

Background

The objective of the VFC program was to flight validate a pneumatic forebody VFC system, which uses high pressure nitrogen exhausted through forebody mounted nozzles, as an effective yaw producing device at intermediate and high AOA. Several wind tunnel tests demonstrated the effectiveness of VFC in producing yawing moments from 15 to 50 degrees AOA. These wind tunnel tests were instrumental in determining flight test requirements, such as optimal nozzle configurations, mass flow requirements, and selection of specific maneuvers and operating limitations. An accelerated design and development of the VFC system allowed installation and aircraft modification to take place in a short amount of time. The X-29 technology demonstrator was chosen to be the testbed due to its capabilities to sustain and maneuver at high AOA. All aspects of preparation for flight test came together for a successful first flight and VFC firing on 27 May 92. The ensuing 58 flights showed VFC to be effective in yaw response up to 52 degrees AOA. Besides improving AOA maneuverability, VFC technology will enable next generation fighters to operate with reduced or no tail structure, thereby improving stealth capabilities and reducing structural concerns.



New Long Service Life Hybrid Ball Bearings

Payoff

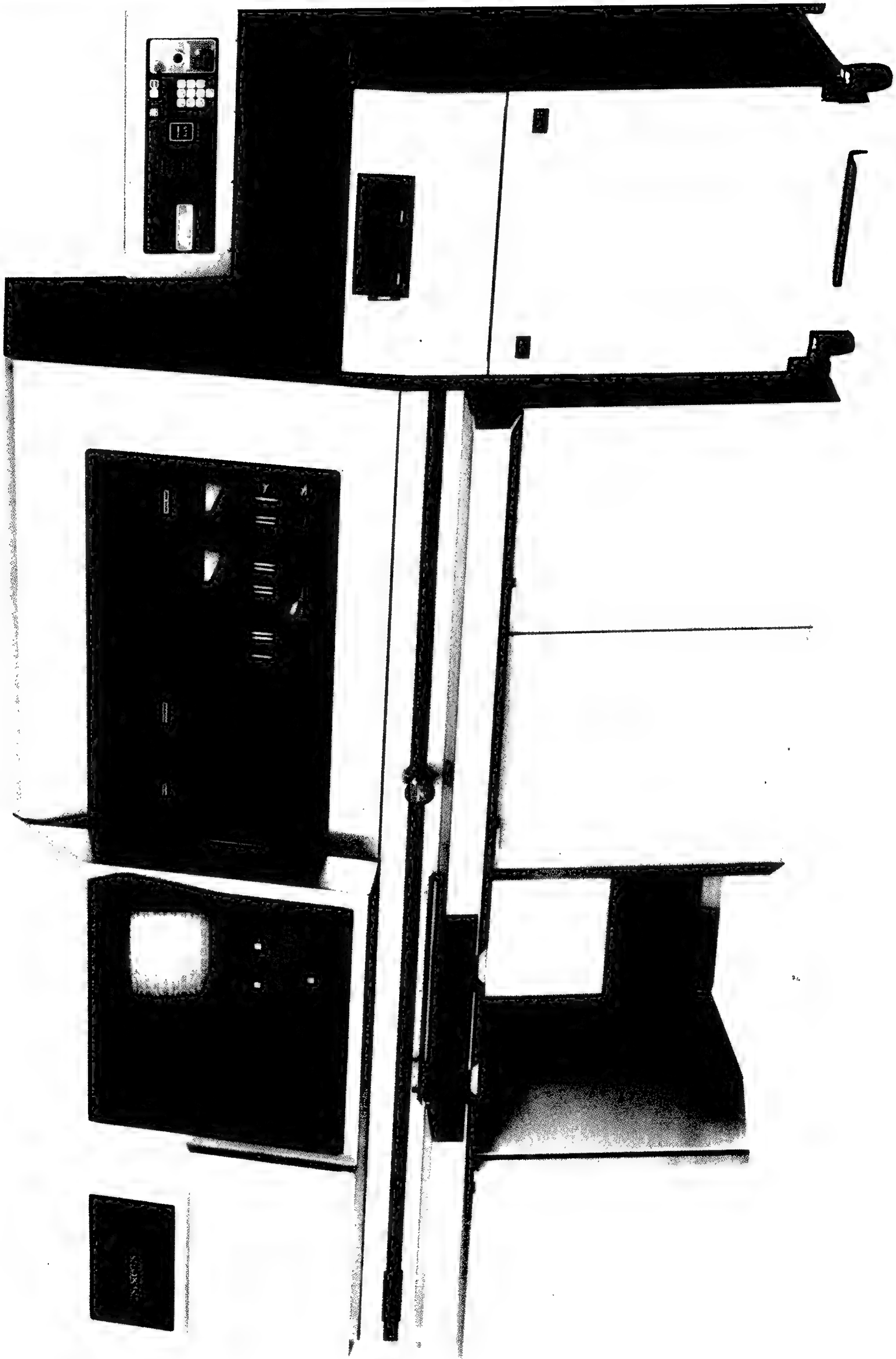
Hybrid ball bearings (such as the disassembled one shown left) can greatly simplify or possibly eliminate the need for external lubrication while greatly increasing bearing life. Systems may be able to operate at higher temperatures using these new bearings. The bearings represent a technology advancement for a wide range of Department of Defense and civilian applications, i.e., precision spindles in the machine tool industry and dental drills. Substitution of these new bearings in the space shuttle's main engine turbopump could save millions of dollars by eliminating the need to rebuild it after each flight.

Accomplishment

Materials Directorate scientists have demonstrated new, long service life, hybrid ball bearings that have a self-lubricating separator. In a full-up ground test of a space shuttle turbopump, the hybrid bearings operated for a total time of 2,500 seconds accumulated during five separate runs without maintenance or a failure. Conventional metallic bearings typically provide only 60 seconds of operating time without replacement. Results of this test represent a 4,000 percent increase in bearing life.

Background

Ball bearings are a critical component in the rotating components of machinery. In the Air Force, the performance of equipment with ball bearing subsystems could determine the degree of success with which a weapon system completes its mission. Ball bearings currently in use are made entirely from metal and require external lubrication. In deployed systems that cannot return to base for lubricant replenishment, provisions must be designed into the weapon or space system to provide the required lubrication. Even with the required lubrication, conventional bearings working in severe duty environments experience short life spans. The new hybrid bearings use different materials with characteristics best suited to the functions each of the bearing components must perform. The hybrid ball bearings use silicon nitride ceramic balls, steel inner and outer races and a Materials Directorate developed fiber reinforced polyimide composite self-lubricating separator. NASA's George C. Marshall Flight Center tested the new bearings under conditions that simulated operation of the space shuttle's main engine turbopump. Under the severe conditions of high speed, heavy load and exposure to cryogenic oxygen, the new bearings performed successfully for over seven hours.



New Holographic Wafer Inspection Technology

Payoff

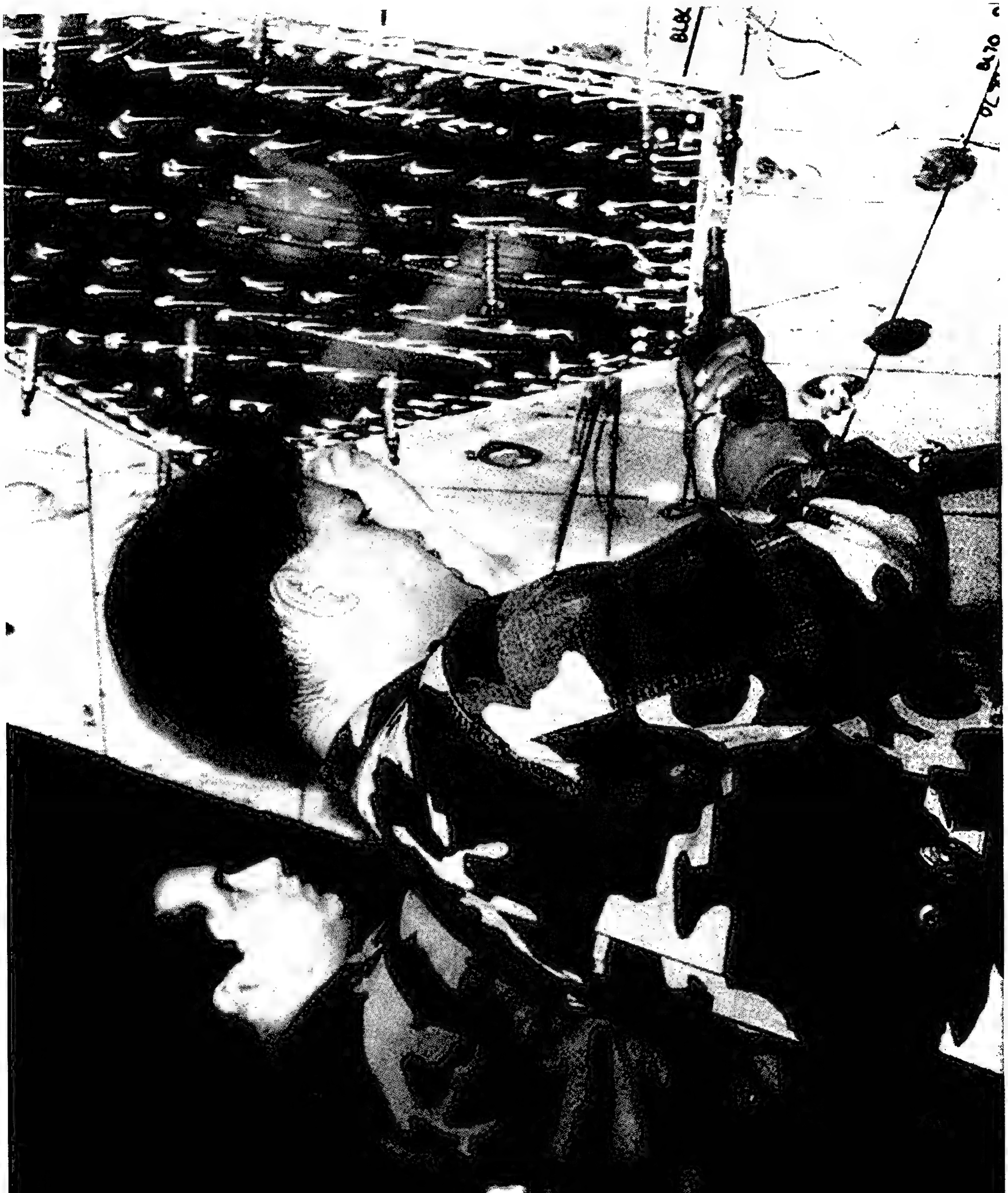
The holographic wafer inspection workstation shown on the left contains many improvements derived directly from program results and user feedback. The inspection process can be applied in production facilities for silicon wafers used in military or commercial integrated circuit fabrication. For the Air Force, this technology improvement means lower costs and shorter lead time. Extensive transfer of this technology improvement has taken place. The majority of SEMATECH (semiconductor consortium) member companies now use this technology.

Accomplishment

A new silicon wafer inspection technology developed under a program sponsored by the Manufacturing Technology Directorate enables detection of whole wafer defect patterns and process signatures which can lead directly to specific process problems. The holographic wafer inspection system developed by Optical Systems Inc., CA generates holograms that serve as permanent 3-dimensional records of process anomalies.

Background

Historically, the optical microscope has been the primary tool for defect detection and evaluation of silicon wafers in integrated circuit fabrication. As minimum feature sizes shrink, magnifications are increased, but field of view and depth of focus both decrease, dramatically decreasing inspection area for a given inspection time. Existing automated inspection methods are also inefficient for present and future wafer technology. Pixel by pixel methods are slow, and light scattering methods are not suited for detecting embedded or planar defects. The contractor was tasked to evaluate holographic wafer inspection technology. Holographic technology was applied to wafer inspection through the development of a holographic wafer inspection system by Optical Systems Inc., CA. A hologram of the wafer is used for inspection and serves as a permanent 3-dimensional record of process anomalies. Inspection can be performed in-line or off-line in more detail. A new wafer inspection philosophy is emerging as a result of the success of this program. Rather than the traditional "defect accounting" methods, process improvement emphasis has shifted to the detection of whole wafer defect patterns and process signatures which can lead directly to specific process problems. The holographic inspection system is a defect problem solver rather than just a defect finder and counter. It sees a broader and more diverse base of defects than has been available through prior technologies. Extending beyond mere defect measurement, this capability can help to identify trends that are traceable to specific process steps.



Rapid Repair of Integral Fuel Tanks

Payoff

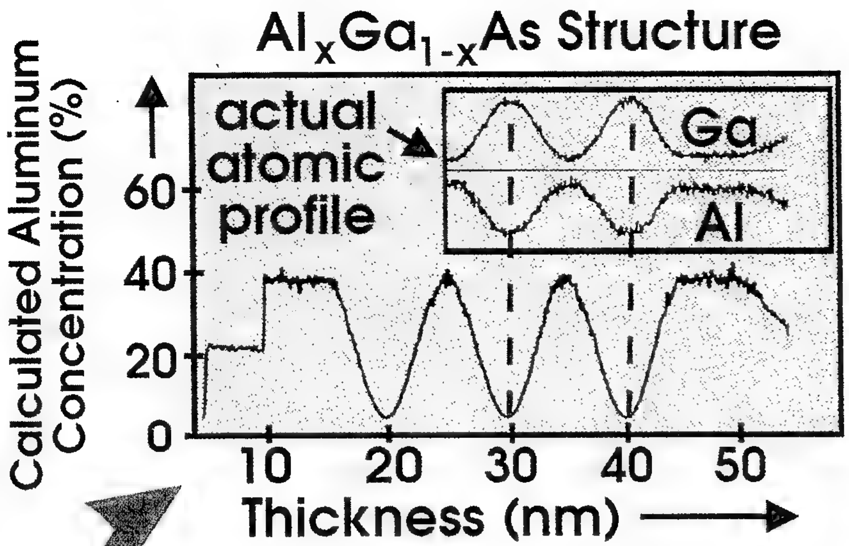
The new repair concepts for aircraft integral fuel tanks reduce repair time in half by significantly reducing the number of fasteners required to effectively transfer structural loads. They are applied easily, use minimal tools and material, and can be performed under the constraints of chemical/biological warfare gear. These repair concepts will be incorporated in the aircraft battle damage repair (ABDR) technical order. A training video will be delivered to all ABDR schools.

Accomplishment

The Vehicle Subsystems Division of the Flight Dynamics Directorate has developed and validated new repair concepts for aircraft integral fuel tanks that are a significant improvement over current battle damage repair techniques. These concepts are compatible with the concept of ABDR.

Background

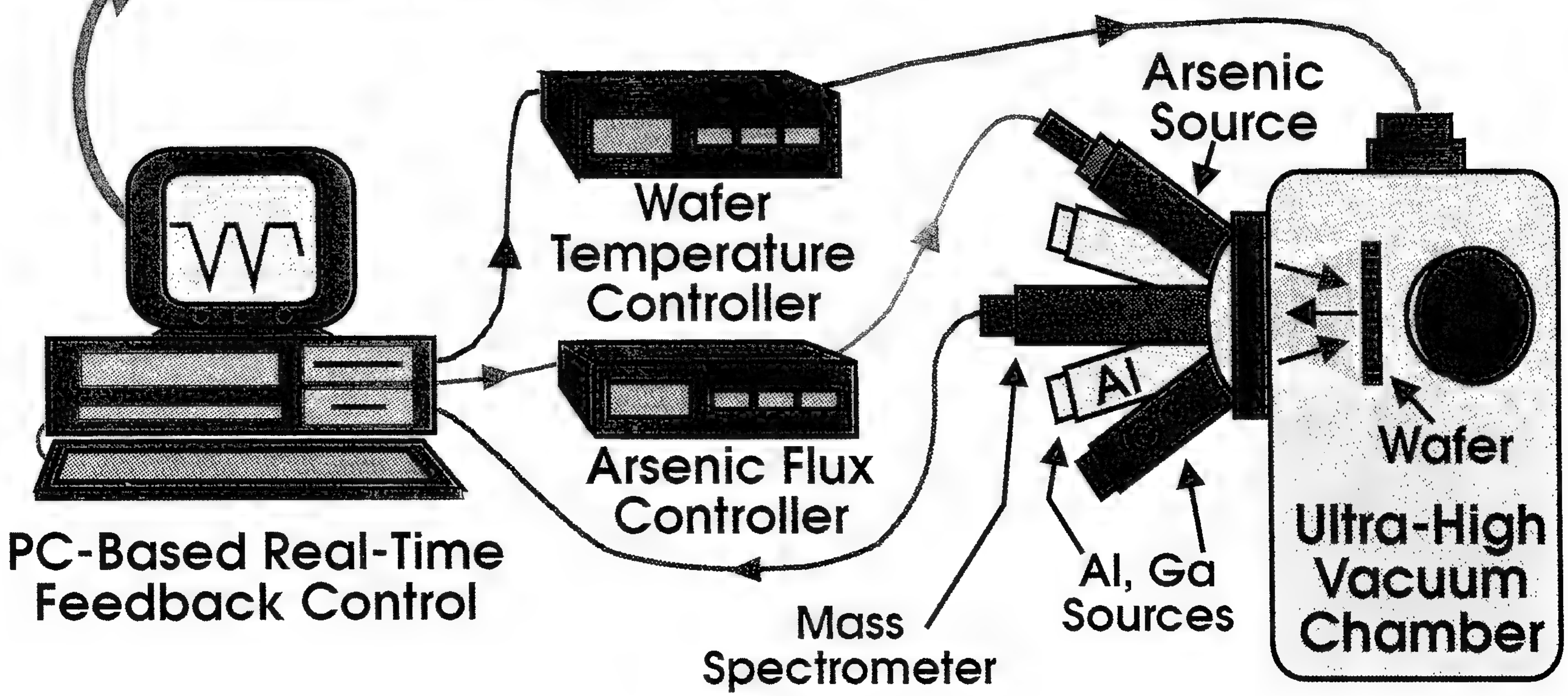
In an austere combat environment, the Air Force must be able to launch, recover, service, load and relaunch aircraft several times a day to employ effective airpower. A significant number of aircraft will return battle damaged and must be repaired as quickly as possible. In order to fulfill this ambitious goal, the US Air Force has implemented an operational maintenance concept called ABDR. The objective of the ABDR program is to enhance the capability to accomplish rapid assessment and repair of battle damaged aircraft as a means to increase wartime aircraft availability and sortie rates. A major time consumption of the ABDR process is integral fuel tank repair. The current concept for battle damage repair of aircraft integral fuel tanks involves mechanically fastening a metallic patch and applying a polysulfide fuel tank sealant, which is not a load carrying material. To transfer structural loads effectively, numerous fasteners are needed; therefore, much time is spent drilling holes and attaching the fasteners. Also, there are problems with short shelf lives and long cure times of current fuel tank sealants. To address this, the Vehicle Subsystems Division initiated and directed a program to develop improved aircraft integral fuel tank repair concepts. These concepts were developed for large battle damaged areas to restore structural integrity and fuel sealing capability allowing the aircraft to be returned to service within approximately 24 hours. The new aircraft integral fuel tank repair concepts use a load carrying adhesive which reduces repair time and the number of required parts in half.



Benefits

The enhanced ability to monitor and control growth parameters has the following impact:

- Improved reliability
- Improved yield
- Improved flexibility
- Reduced process time
- Reduced cost



In-Situ Sensor Control of Crystal Growth Parameters

Payoff

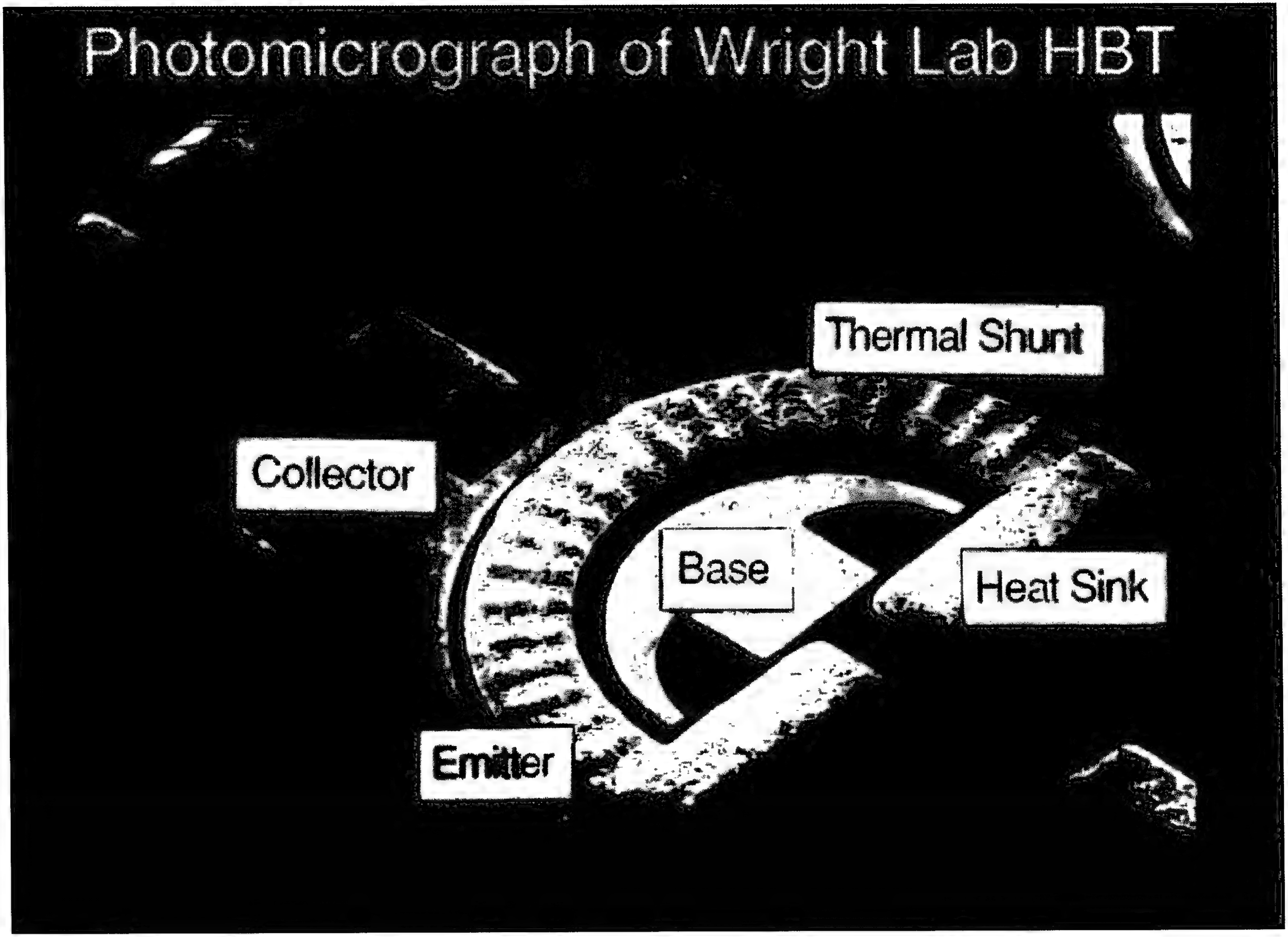
The integration of in-situ sensors into the growth chamber depicted on the left will improve the ability to control crystal growth parameters and improve the crystal growth process in several ways. This capability increases the solid state device engineer's freedom in designing novel electronic and photonic devices and paves the way for a whole new generation of high-speed microwave and digital devices. The importance of the capability is evidenced by the initiation of several Cooperative Research and Development Agreements with industry.

Accomplishment

Research developments in the Solid State Electronics Directorate have led to the unprecedented ability to reproducibly control the growth of advanced crystalline structures having virtually any desired alloy composition profile. The Directorate's findings greatly increase the freedom in designing advanced device structures and provides the potential to revolutionize the field of solid state device technology. These accomplishments have resulted in four patents pending.

Background

Previous attempts at producing complicated crystal structures for advanced electronic and photonic device applications have largely been limited to simple layered structures. The Directorate's experimental molecular beam epitaxy (XMBE) team's findings have led to the ability to reproducibly control the growth of advanced crystalline structures having virtually any desired alloy composition profile. The XMBE team, led by Dr. Keith Evans, leads the international research community in the use of in-situ sensors (which are integrated into the growth chamber as an integral part of the growth process) for improving the understanding of the molecular beam epitaxy (MBE) crystal growth process. After first establishing an internationally recognized effort in understanding the physics and chemistry of the MBE growth process, Dr. Evans' team demonstrated the utility of the in-situ sensor technique, desorption mass spectrometry (DMS), for improving the understanding of the fundamentals of MBE growth technology. They also demonstrated that DMS can be used as a tool to monitor MBE growth parameters much more directly than previously thought possible. Recent successes in implementing DMS in real-time feedback loop for continuous control of MBE growth parameters has led to the unprecedented ability to reproducibly control the growth of advanced crystalline structures. This technology also permits the growth of thin epitaxial layers whose dimension approach those of an atomic monolayer.


Photomicrograph of Wright Lab HBT
Thermal Shunt
Collector
Base
Heat Sink
Emitter

High Power Density Microwave Heterojunction Bipolar Transistors

Payoff

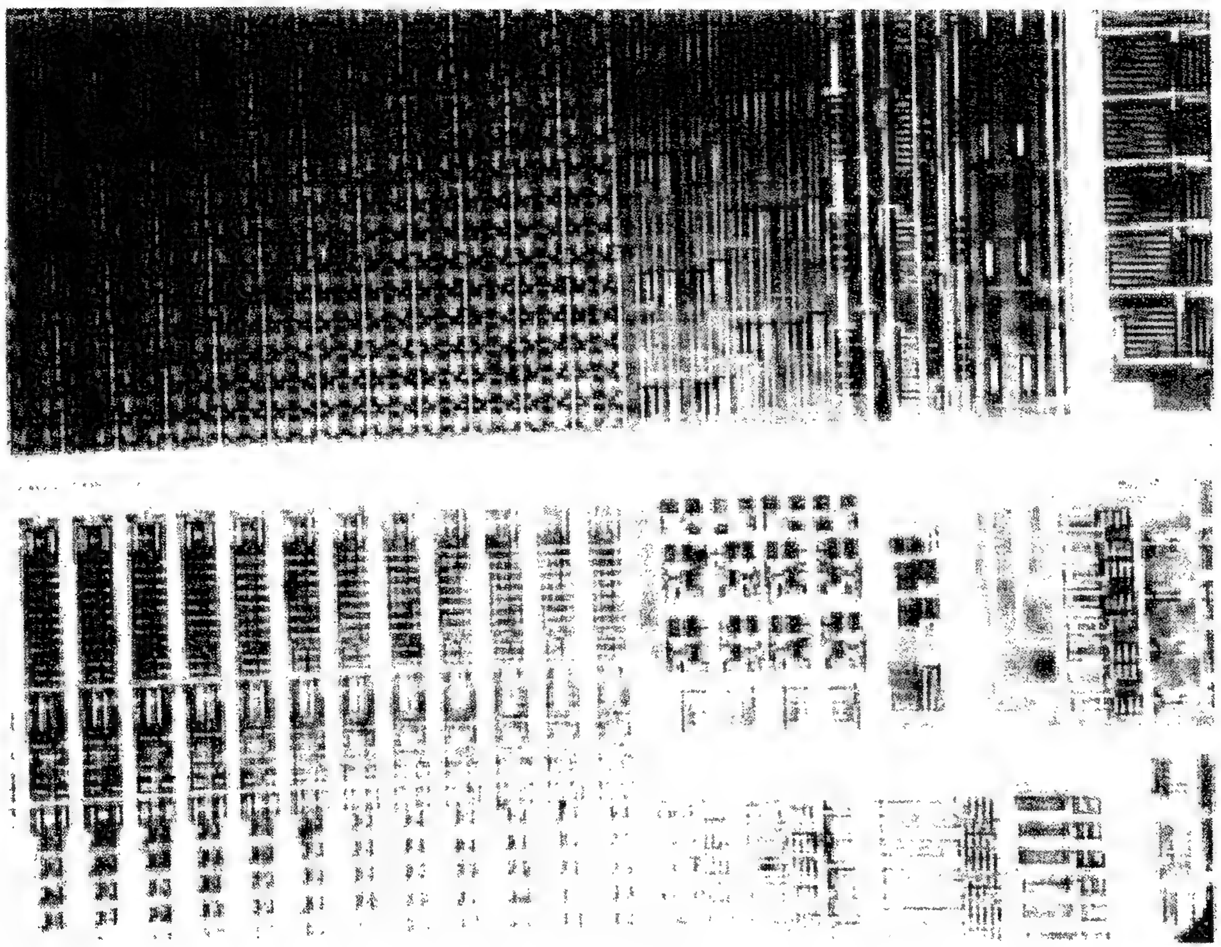
An innovative thermal shunt approach has eliminated the heterojunction bipolar transistor (HBT) thermal instability problem. This thermal shunt approach is equally applicable to HBTs based on other semiconductor material systems. It represents a breakthrough in the technology which will impact the performance, efficiency and cost of all classes of systems that use solid state microwave power generation. The importance of this breakthrough is evidenced by the numerous requests for the technology received from leading industrial research and development laboratories such as Hughes, Rockwell, Westinghouse and Raytheon.

Accomplishment

The Solid State Electronics Directorate's Research Division has developed a thermal shunt technique both in theory (modeling) and practice (fabrication) for solving the thermal runaway problem of HBTs. They demonstrated A1GaAs/GaAs HBTs with an output power of 10 mW/um^2 at 10 GHz with 7 dB gain and 60% power added efficiency in continuous wave (CW) mode. This high power density is 3 times higher than the previous CW operation record, and is reaching the device electronic limitations.

Background

There is a great demand for high-performance solid state microwave power devices in modern warfare and commercial electronic systems. This is reflected by widespread interest in the development of the newest of device structures, the HBT. HBTs are being developed for high power microwave applications based on their high power density and high efficiency capabilities. Although the power densities demonstrated with A1GaAs/GaAs HBTs are high, they fall considerably short of the values expected from electronic limitation due to a thermal runaway problem. This thermal instability of bipolar transistors originates from the fact that the emitter-base junction has a negative temperature coefficient. The Division's HBT modeling effort showed that the conventional method of electrically connecting multiple devices (emitter fingers) in parallel resulted in a weak thermal connection, such that localized hot spots form at a threshold power density and cause thermal runaway. A prevailing solution is to incorporate a ballast resistor either in the emitter or base of an HBT to relieve, but not eliminate, the thermal instability problem by moving its occurrence to a higher power operating condition. The inclusion of ballast resistors in HBTs adds extra processing steps to the device fabrication procedure, degrades device performance and decreases device yield. The thermal shunt approach developed here incorporates a thick metal heatsink which connects emitter fingers to force a unification of junction temperatures. This innovation eliminates the HBT thermal instability problem without increasing processing complexity and enhances the device performance by reduçing the HBT's thermal resistance and hence its junction temperature.



partial view of

4kBit SRAM

**Included are:
Memory Array,
Decoder,
and
Timing Circuit**

Complementary Heterostructure Field Effect Transistor Technology

Payoff

Complementary heterostructure field effect transistor (C-HFET) technology combines the high speed capability of compound semiconductor devices with the high density, low power dissipation of complementary field effect transistor logic. Shown on the left is a 4k Bit static random access memory (SRAM) circuit that can operate at a clock frequency of up to 500 MHz. C-HFET circuits will find application in military systems where high computational power and low power dissipation are needed. This technology was successfully transferred to Motorola for further optimization and system applications, i.e., commercial cellular communication products.

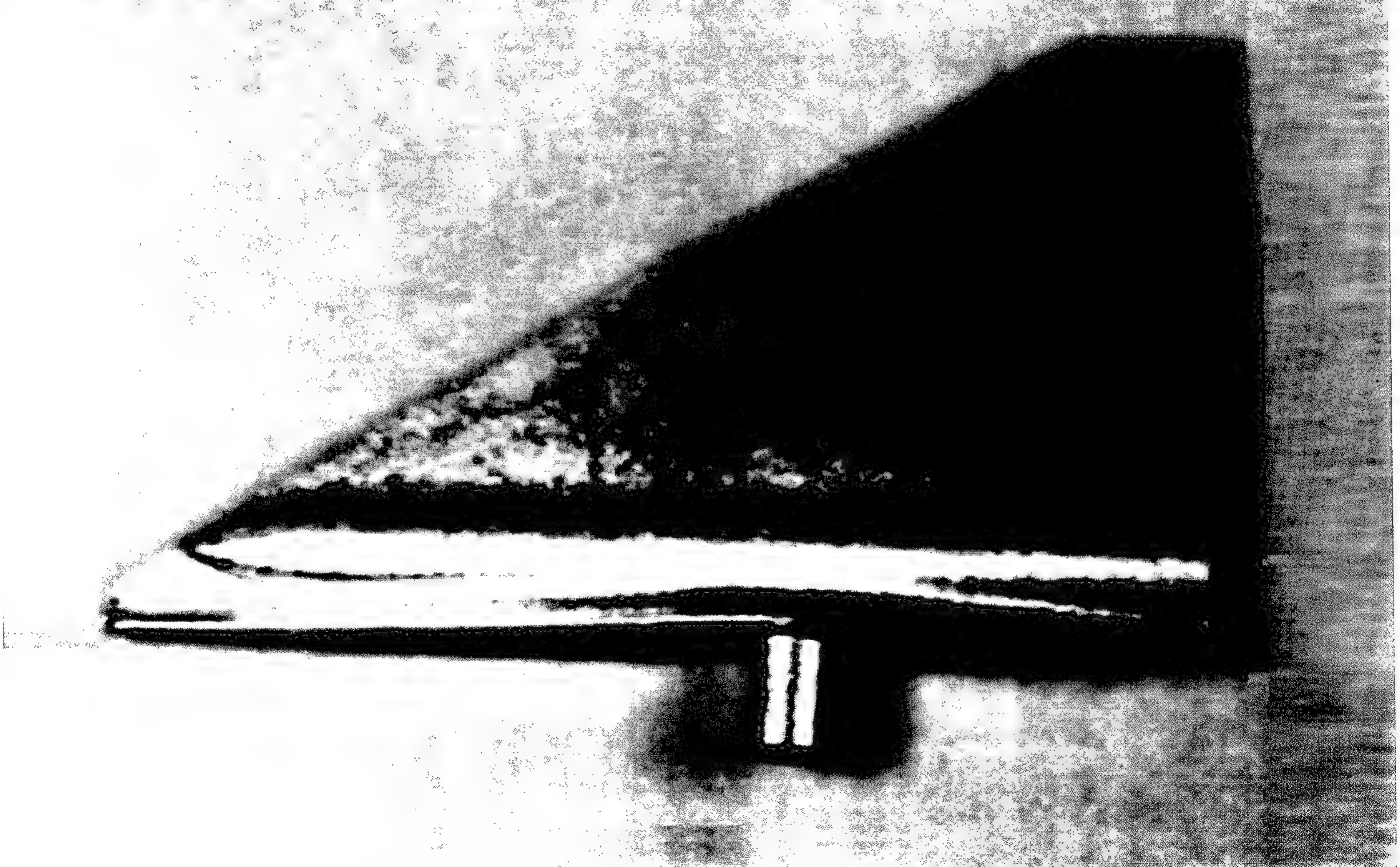
Accomplishment

Under the sponsorship of the Solid State Electronics Directorate, Honeywell successfully developed and demonstrated C-HFET technology, using the molecular beam epitaxy-grown AlGaAs/InGaAs/GaAs pseudomorphic (irregular form) materials structure. Logic and memory circuits were demonstrated in the C-HFET technology, including a 4k Bit SRAM operating at a clock frequency of up to 500 MHz.

Background

The compound semiconductor technology has been providing microelectronic circuits for high performance systems for many years. The next generation compound semiconductor technology requires a significant increase in gate density without a sacrifice in clock speed. The C-HFET technology addresses this need. It will increase the circuit density by one to two orders of magnitude without a clock speed penalty. This technology will provide circuits for satellite applications; one example is Iridium, a commercial satellite system for worldwide cellular telephone communications. State of the art silicon technology has problems addressing this application due to its large power dissipation stemming from the large circuit complexity. The C-HFET technology operates at much reduced supply voltage levels without significant impact on clock speed, thereby reducing power dissipation. The power dissipation is proportional to the square of the supply voltage. While this technology will have critical impact on space and battery operated systems, the need for low power and high density at high clock rates is becoming more and more important for all advanced DOD systems.

Cast Titanium Missile Control Fin



New Titanium Casting Technology Saves Weight and Lowers Costs

Payoff

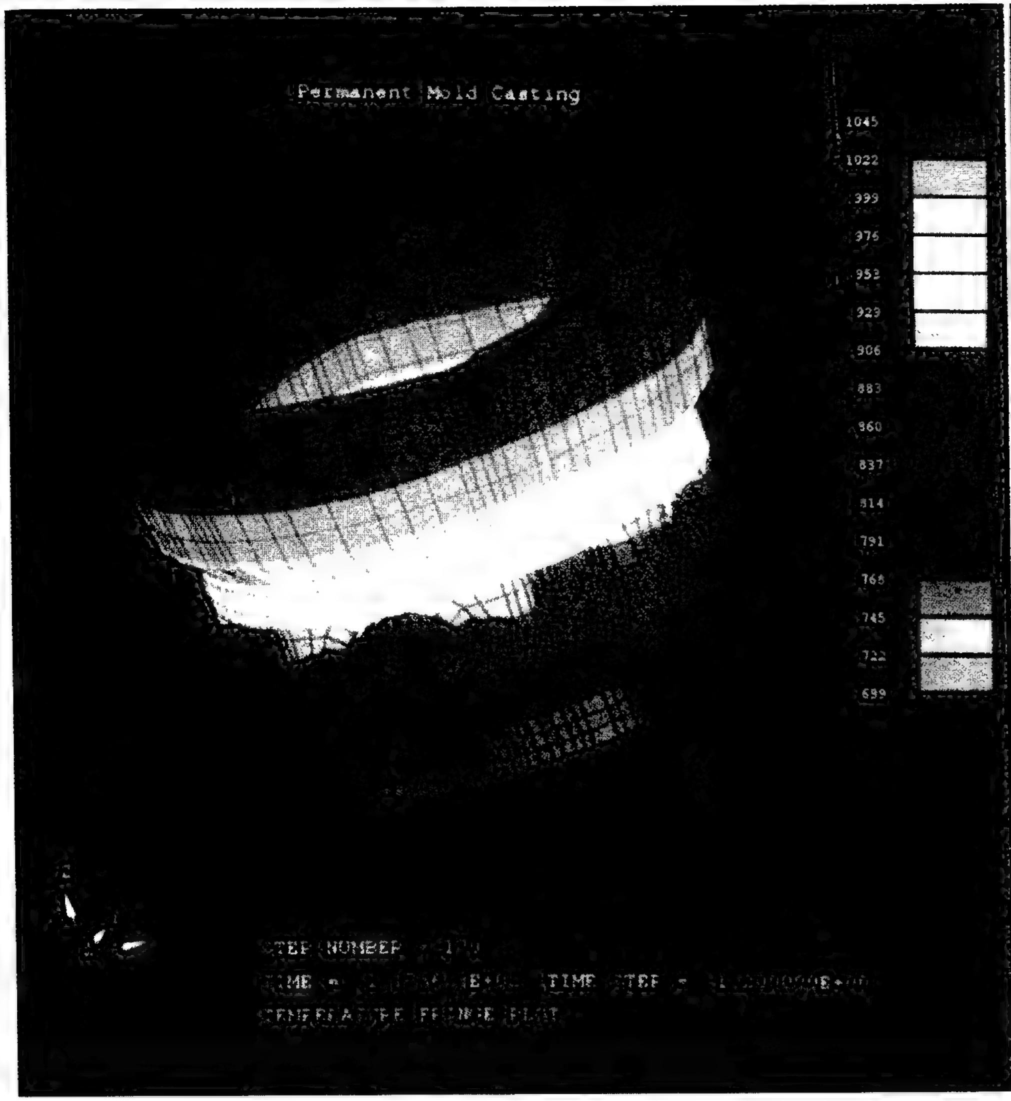
The new casting technology enables the fabrication of cast components (such as the cast titanium missile control fin shown left) for both military and commercial aerospace systems at 20 - 50 percent less weight and up to 30 percent lower cost. The reduction in the variability in cast titanium mechanical properties will contribute to foundry technology for a broad range of both civilian and military applications.

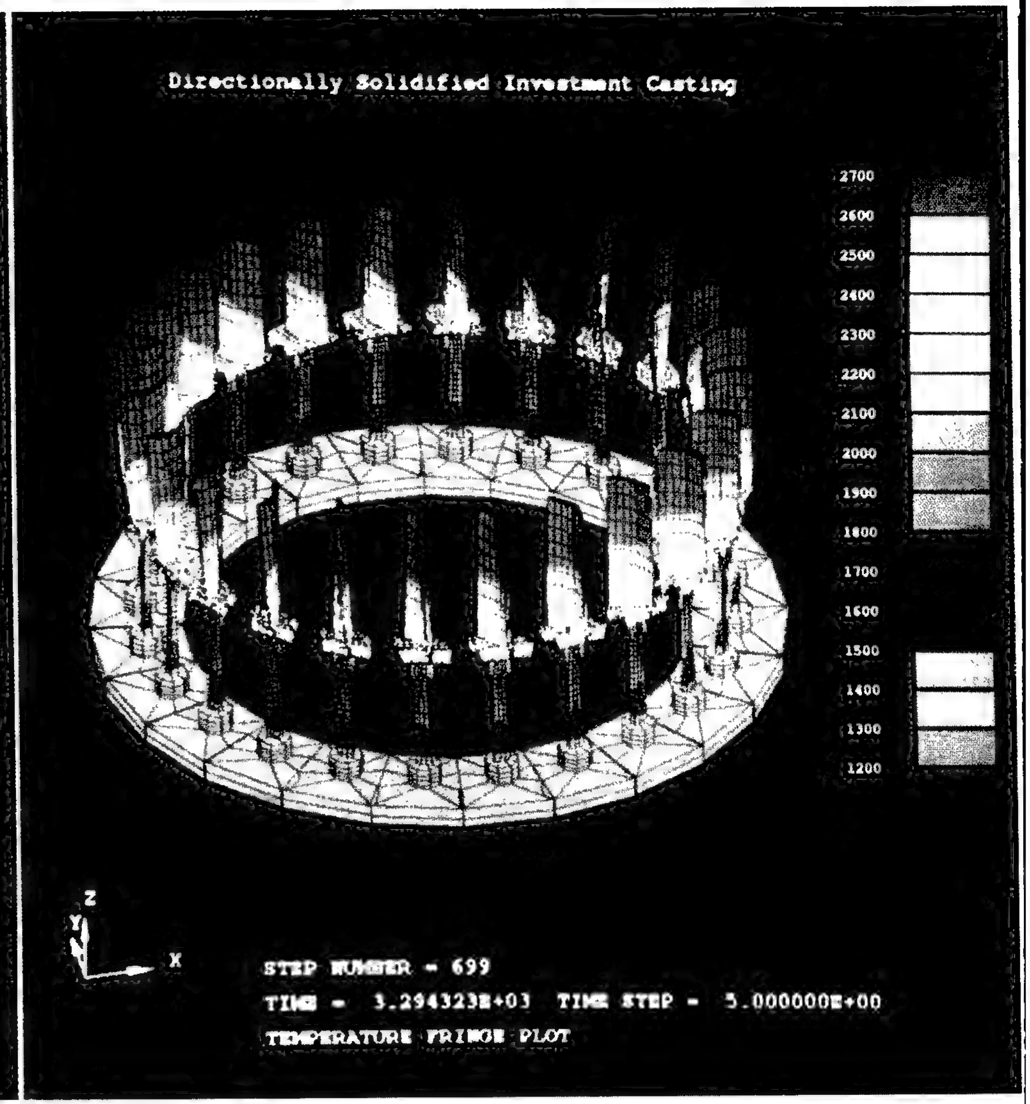
Accomplishment

Under the sponsorship of the Materials Directorate, McDonnell Douglas Missile Systems Company has demonstrated titanium -6 aluminum -4 vanadium (Ti-6Al-4V) castings that are weight competitive with aerospace quality forged and machined parts and cost less to produce.

Background

Casting is a cost-effective method for fabricating metal parts when compared with forged and machined metal parts. However, castings have not been widely used for aerospace applications because of variability in mechanical properties. Airframe designers have traditionally applied a "casting factor" to account for these variations. The "casting factor" increases the cross-sectional area to reduce stress and often increases the weight of cast parts above that of equivalent forged and machined parts. The increased weight usually eliminated castings from use in flight systems. McDonnell Douglas Missile Systems Company found a way to reduce the variability in mechanical properties. This has made cast Ti-6Al-4V alloy a more viable material for use in aerospace applications. The effort used Taguchi methods (design of experiments to determine factors that cause variability of data) to determine that casting chemistry and postcasting treatments were the sources of variability. The contractor utilized a nondestructive inspection technique to verify the quality of the castings. The inspection technique correlates the results from mechanical properties analyses with microstructural features. A new aerospace materials specification and new casting design allowables called "A" and "B" are being developed. These design allowables ensure that 99 percent ("A") or 90 percent ("B") of the castings will exceed a specified strength with 95 percent confidence level. Durability and damage tolerance information has been developed to facilitate the transition of Ti-6Al-4V casting technology into aerospace systems. The commercial aviation industry has expressed keen interest in the results of this program since the castings will save weight (increase payload) and reduce cost.


Permanent Mold Casting
1045
1022
999
976
953
929
906
883
860
837
814
791
768
745
722
699


Directionally Solidified Investment Casting
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
Z
Y
X
STEP NUMBER = 699
TIME = 3.294323E+03 TIME STEP = 5.000000E+00
TEMPERATURE FRINGE PLOT

Air Force Casting Model Helps U.S. Industry Become More Competitive

Payoff

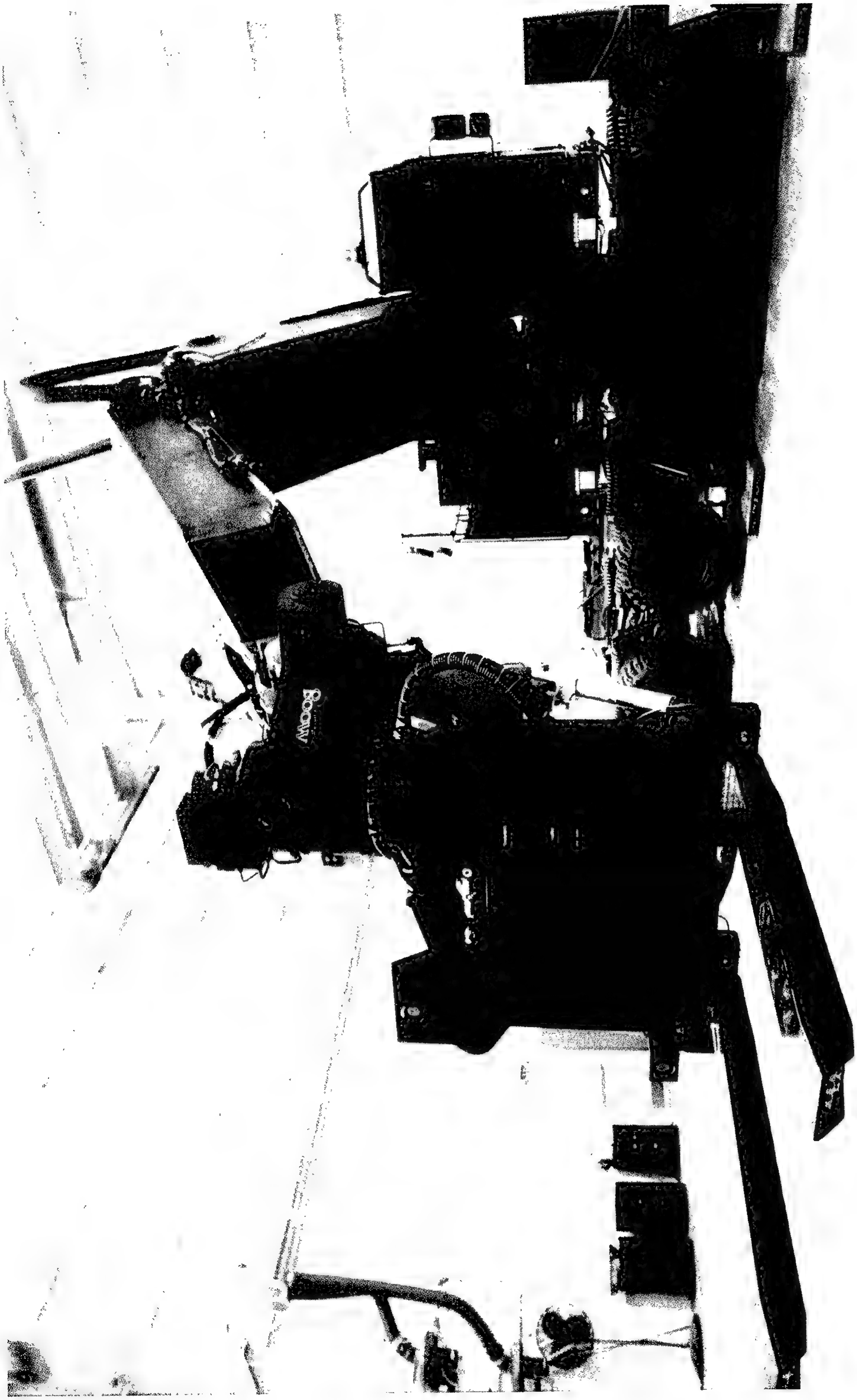
Depicted on the left are temperature profiles that resulted from modeling two different types of castings used in separate applications. The model was a key factor that enabled CAST-FAB of Cincinnati, OH to win an order for very large castings from a German firm over competing German casting manufacturers. Another user, General Electric, has estimated an annual savings in excess of $50M by using the model.

Accomplishment

Materials Directorate engineers, working with Universal Energy Systems (UES) Inc., Beavercreek, OH developed and transferred to industry a unique computer model that simplifies the casting of metal parts. This unique finite element computer model reduces the cost and improves the quality of cast components by eliminating the guess work involved in the conventional shop floor trail and error process.

Background

Casting involves the flow of molten material into a die or mold and cooling the liquid until it solidifies. Materials engineers from the Directorate's Metals and Ceramics Division responded to user needs and initiated the development of a unique finite element computer model that accurately predicts the flow of the molten material into the die cavity, the heat transfer throughout the operation and the solidification of the final cast part. Materials Directorate engineers publicized the model through publications and presentations and UES continues to actively market the model software. Model users include Ford Motor Company, General Motors, ALCOA, General Electric, Massachusetts Institute of Technology and several National Laboratories. NASA conducted an independent study of available casting models and selected the model developed by the Air Force and UES for use since it proved to be the most complete and accurate. Air Force funds invested in development of the model totaled approximately $300,000. The model is gaining wider acceptance and continues to be transferred to industry. It saves millions of dollars annually for its users and enables them to become more competitive. Over 30 industrial, academic and government organizations are actively using the casting model for both research and production work.



Drive-Reinforcement (D-R) Learning Controller Applied to Robotics

Payoff

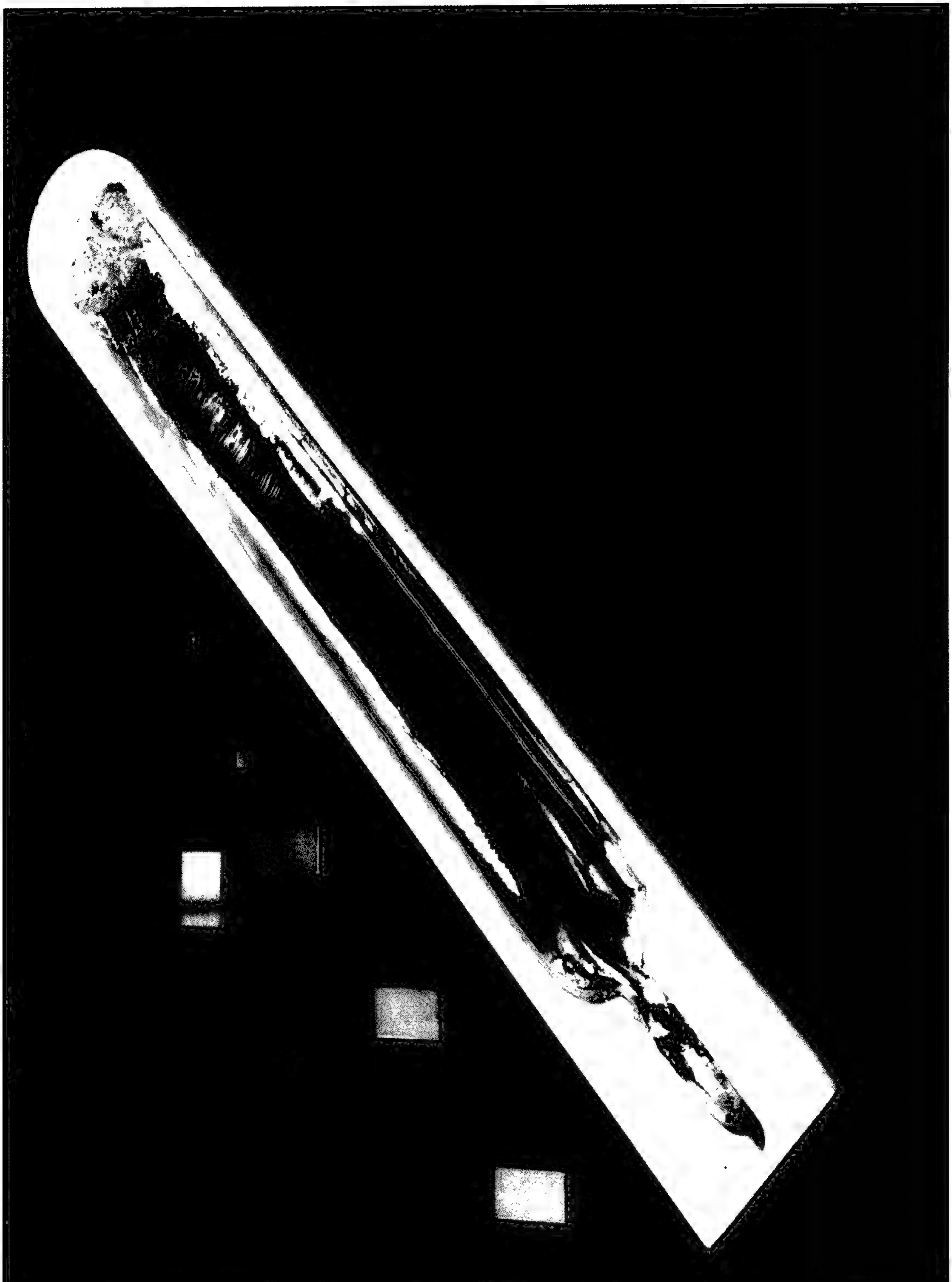
Using internal funding, Martin Marietta will apply the drive-reinforcement (D-R) learning controller developed by the Avionics Directorate to a six-degree-of-freedom field materiel handling robot (shown left) which was designed for handling pallets of ammunition and hazardous waste. The new D-R controller will improve robot arm performance by coordinating learned movements on-line and in real time, and adapting to wear, thus increasing robot arm accuracy and reliability.

Accomplishment

The Avionics Directorate has developed a learning mechanism for machine intelligence which Martin Marietta Aero & Naval Systems has applied to the control of a two-degree-of-freedom robot arm. The D-R learning controller is easier to implement and yields smoother and more efficient movement than conventional controllers and adapts to changing plant characteristics on-line and in real time.

Background

D-R machine learning is a product of in-house basic research conducted in the Avionics Directorate. In a journal article published in 1988, Dr. Harry Klopf demonstrated that his D-R model of nervous system function successfully accounted for a wide range of animal behavior observed by experimentalists. Subsequent research by Dr. Klopf, Mr. James Morgan and Capt Leemon Baird has led to proof that the D-R model is capable of controlling dynamical systems. Under a contract with Martin Marietta Aero & Naval Systems, a D-R-based controller that is capable of learning the appropriate joint movements to move the end effector of a two-degree-of-freedom robot arm smoothly and efficiently along a commanded trajectory was developed and successfully demonstrated (a four-minute videotape is available). The design and evaluation of controllers for robotic arms with multiple degrees-of-freedom consumes engineering resources out of proportion to the added degrees-of-freedom because the control of such arms is highly nonlinear. Martin Marietta estimates that a controller based on D-R learning will require less than a tenth of the time needed to develop and evaluate an equivalent conventional controller. A D-R controller improves performance by coordinating simultaneous roll, pitch, and yaw, yielding smooth, learned movements rather than the jerky and inefficient movements that are a consequence of issuing sequential, independent commands. Robots with a long or stressful operational life experience wear that decreases accuracy and reliability. Because of its ability to learn on-line and in real time, a D-R learning controller will readily adapt to wear. Martin Marietta will be applying this technology to the control of teleoperated fork lift trucks, specifically a field materiel handling robot which will be used by the Army to move pallets of ammunition safely and rapidly. The Department of Energy is considering a version of the field materiel handling robot to remove toxic and radioactive waste without exposing personnel to hazardous conditions.



New Electro-Optical Crystals Improve Countermeasure Systems

Payoff

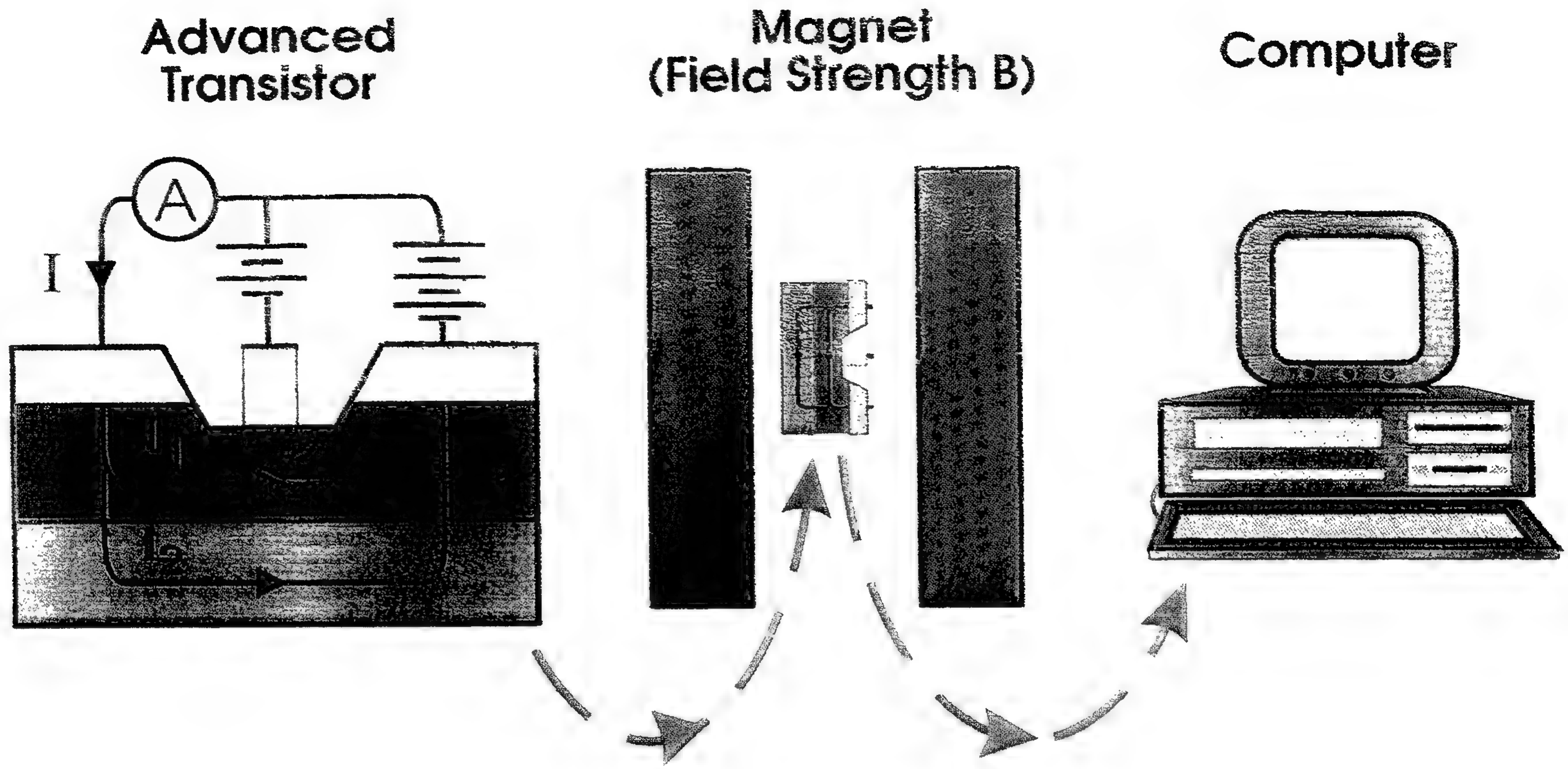
The use of zinc-germanium-phosphide crystals (shown left) in tunable infrared (IR) laser systems will enable future infrared countermeasure systems to neutralize hostile threats more readily and increase Air Force system survivability. Also, as part of a remote pollution monitoring system, the infrared parametric oscillator will allow rapid and accurate determination of air pollutants and their sources.

Accomplishment

Research, led by scientists in the Materials Directorate, has resulted in the growth of large zinc-germanium-phosphide crystals for use in tunable IR laser systems. These crystals make possible the development of solid-state IR parametric oscillators that emit a continuous band of IR radiation over a wide range of wavelengths.

Background

The conflict in the Mid-East against Iraqi military targets proved the accuracy and firepower of guided weapons. To help protect friendly forces from the same fate, electro-optic countermeasure systems will become available to use against similar enemy weapons. The ability of countermeasure systems to defeat guidance sensors on threatening ordnance determines the survivability of such attacks. To help improve the effectiveness of these defensive systems, the Materials Directorate formed and is leading a team of researchers from Phillips Laboratory, Kirtland AFB NM, Rome Laboratory, Griffiss AFB NY and Lockheed Sanders in Nashua NH, that has proven large crystals of zinc-germanium-phosphide can be produced. These crystals make possible the development of solid-state IR parametric oscillators that emit a continuous band of IR radiation over a wide range of wavelengths. The variable wavelengths are achieved by illuminating the zinc-germanium-phosphide crystal with a single-frequency IR laser and then rotating the crystal about its axis to produce a continuous spectrum of lower frequency IR radiation. This radiation can be used to counter weapon guidance sensors and cause them to become ineffective. In addition, zinc-germanium-phosphide oscillators can be used for many other applications such as to help monitor the atmosphere for the presence of pollution.



Old Technique

Measure at one B.
$I_1 = ?$ $I_2 = ?$

New Technique

Measure at three B values.
Compute I_1 and I_2.

Electrical Properties of Advanced Transistor Materials

Payoff

The electrical properties of advanced semiconductor materials for microwave and digital transistors and circuits are often too complicated to be analyzed by present standard techniques. A revision of an old technique, along with a new computer algorithm, allows detailed analysis of a widely used new class of transistor materials, resulting in the fabrication of superior devices. Martin Marietta, Syracuse NY and Hughes, Torrence CA are beginning to implement this technique in their own testing programs.

Accomplishment

The Solid State Electronics Directorate, supported by Wright State University, developed a new technique in-house that determines the electrical properties of a widely used new class of transistor materials. This new technique will provide increased yields and performance across a range of device technology.

Background

The basic materials used for new high-speed semiconductor device designs must be thoroughly understood in order for the designs to be optimized. Air Force and commercial electronic systems demand ever increasing speeds for the devices used in their circuits. A high-speed device, the high electron mobility transistor (HEMT), was invented about 10 years ago and is being introduced into advanced circuits for electronic systems. This device typically consists of two layers of dissimilar materials, such as gallium arsenide and aluminum-gallium arsenide, with current capable of flowing in both layers. To understand the HEMT for design purposes, it is necessary to be able to determine electron concentration and mobility in each of the two layers; however, conventional electrical characterization techniques, which measure the conductivity and Hall coefficient, are capable of analyzing only one layer. Until now, it has been necessary to create and measure special one-layer test structures, rather than the actual two-layer device structure, a procedure which is costly and often misleading. The new technique still makes use of Hall effect and conductivity measurements, so that no additional equipment is necessary, but uses data taken at three magnetic-field strengths, instead of one. Then a mathematical analysis, along with a special algorithm, allows the electron concentrations and mobilities to be determined in both layers. Many previous attempts to solve this problem have been published in the professional literature, but all of them have either been based on approximations or have required data fitting to complicated mathematical expressions. This new procedure is exact and fast, since the mathematics used have been reduced to a much simpler form.

Hybrid Laminar Flow Control Team Recipient of the Nelson P. Jackson Aerospace Award

Payoff

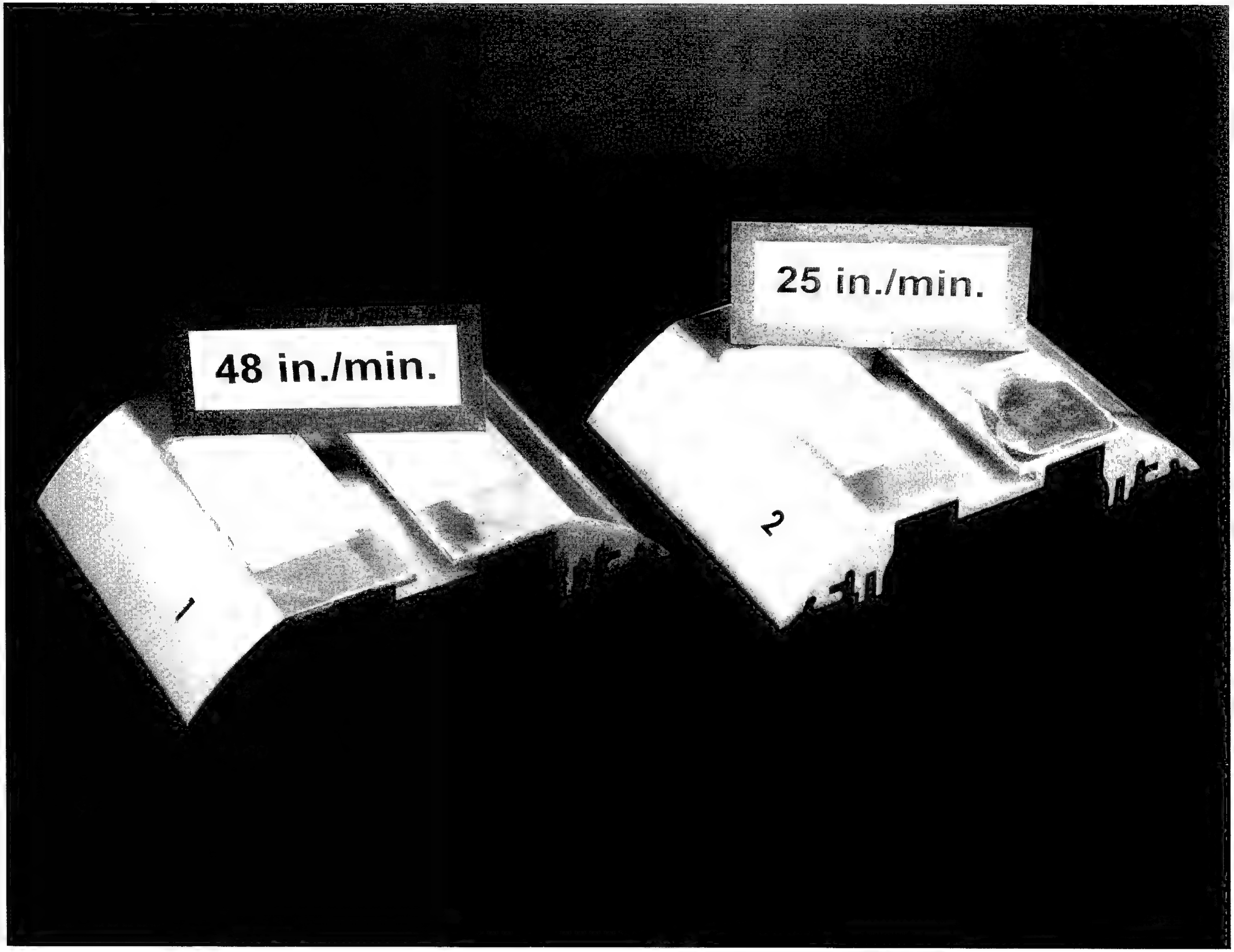
The Government-Industry hybrid laminar flow control (HLFC) team provided the aircraft industry with detailed design data that will provide major improvements in fuel efficiency and performance for the next generation of long range commercial and associated military derivative transport aircraft, such as current generation McDonnell Douglas KC-10 cargo/tankers.

Accomplishment

The Aeromechanics Division of the Flight Dynamics Directorate was honored as part of the Boeing-NASA-Air Force HLFC team at the 36th Annual Goddard Memorial Dinner on 26 March 1993. The HLFC team was selected by the National Space Club to receive their Nelson P. Jackson Aerospace Award given annually for outstanding contributions to the aerospace field. The HLFC flight experiment on the Boeing-757 transport prototype was cited "for superior achievements in the development of advanced laminar flow control technology for future fuel-efficient subsonic transport aircraft." In 1992, the team completed a first-ever flight test investigation which demonstrated the achievement of extensive drag-reducing laminar flow on the wing of an actual commercial aircraft.

Background

The HLFC concept combines both active suction boundary layer control (BLC) and natural laminar flow (NLF) principles. All modifications to the test aircraft were forward of the front wing spar and consisted of a new 22 foot span leading edge panel installed outboard of the left engine nacelle. This test panel incorporates active suction in the outer 17 feet and a new Krueger high lift leading edge flap. This flap is also optimized for prevention of insect contamination and foreign object damage (FOD) to the microperforated titanium suction surface. Previous Aeromechanics Division research flights with the X-21 Laminar Flow Control Aircraft in the 1960's developed the aerodynamic design criteria which were successfully applied in this program. The X-21 also demonstrated the requirement for wing leading edge contamination operations. The directorate's past and recent contributions to this successful program demonstrated the potential for future dual-use DOD research programs.


48 in./min.
25 in./min.
1
2

Air Force Aluminum Extrusion Technology Will Save Industry Over $25 Million

Payoff

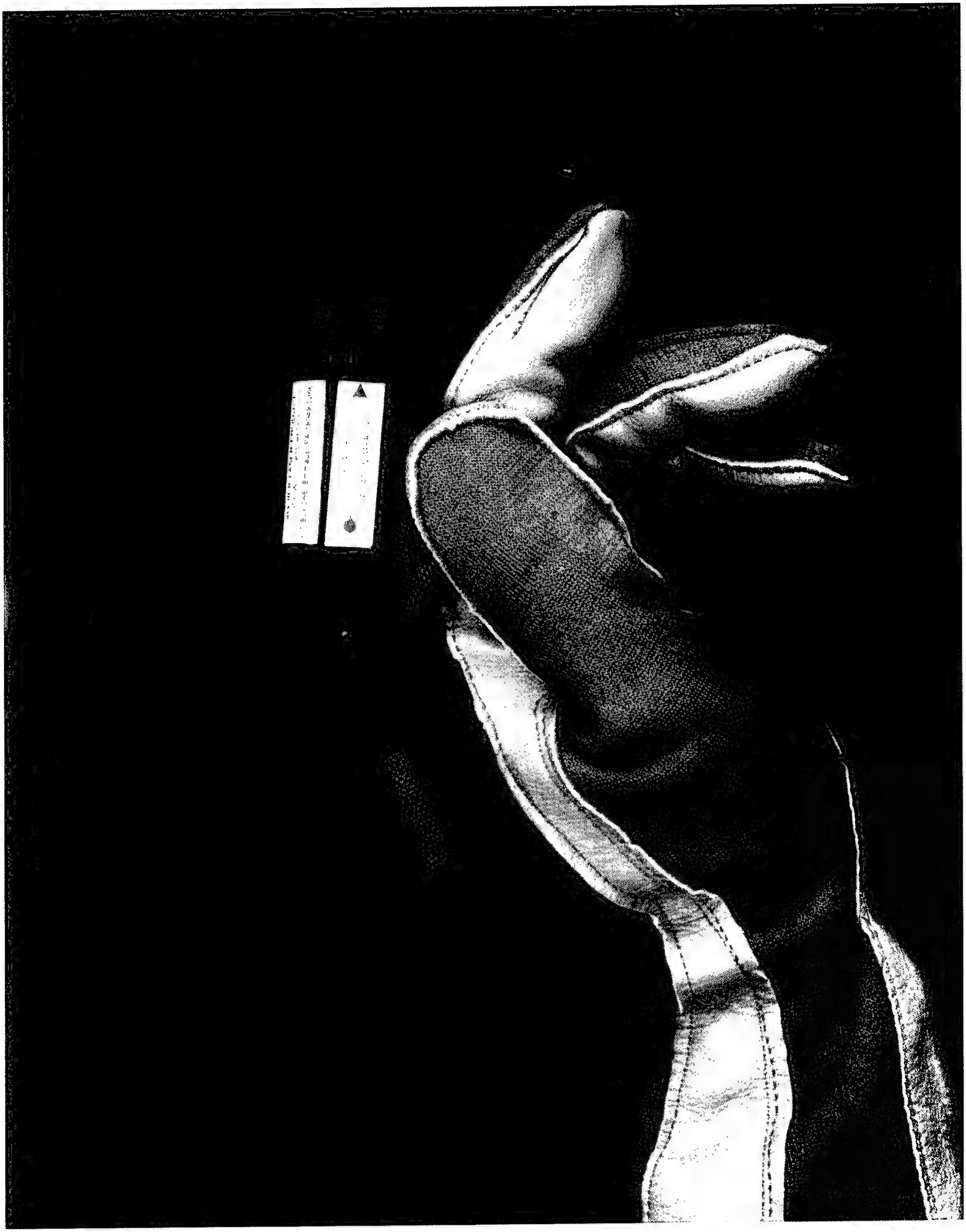
The extrusion samples shown on the left indicate that the aluminum extrusion rate can almost be doubled without sacrificing quality. The Materials Directorate's ongoing participation in the transferring of aluminum extrusion modeling and process control technology through the Technology Development Corporation (TDC), of Youngstown State University OH ensures the continued availability of high quality extruded components from domestic sources for Air Force systems. Full implementation of the technology transferred will save a network of 25 aluminum extrusion firms a total of $25,000,000 in production costs over a period of five years and enable US firms to become more competitive in world markets.

Accomplishment

Assistance provided by scientists at the Materials Directorate in the transfer of aluminum extrusion modeling and process control technology to a group of aluminum extrusion manufacturers will save the manufacturers development cost and time, plus improve their productivity, reduce scrap, die trials and set-up times. This assistance will shorten the implementation cycle for the technology from five years to two years and save $3,750,000.

Background

Extrusion is a material processing method that involves forcing a heated, pliable material through a die to form the desired cross-section. Extruded materials are used in military systems (critical structural elements for aircraft, missiles and satellites), consumer durable goods, construction and transportation. Materials Directorate scientists are working with TDC to transfer material extrusion models and process control technology the directorate developed, to a network of 25 aluminum extrusion firms. Many of these firms are small and have fewer than 20 employees. TDC had contacted the Directorate in late 1991 and requested information and assistance on aluminum extrusion developments. Much of the extrusion technology being used by the network firms was over 40 years old. It involved an empirical approach with repetitive experiments to arrive at die designs and set-up parameters to produce acceptable products. This traditional approach was expensive, time consuming and scrap rates were higher than desired. Using the Air Force developed extrusion model and process control software, the firms can determine the proper die design and processing conditions that produce high quality extrusions on the first try.



Finger-Mounted Laser Technology Transfer

Payoff

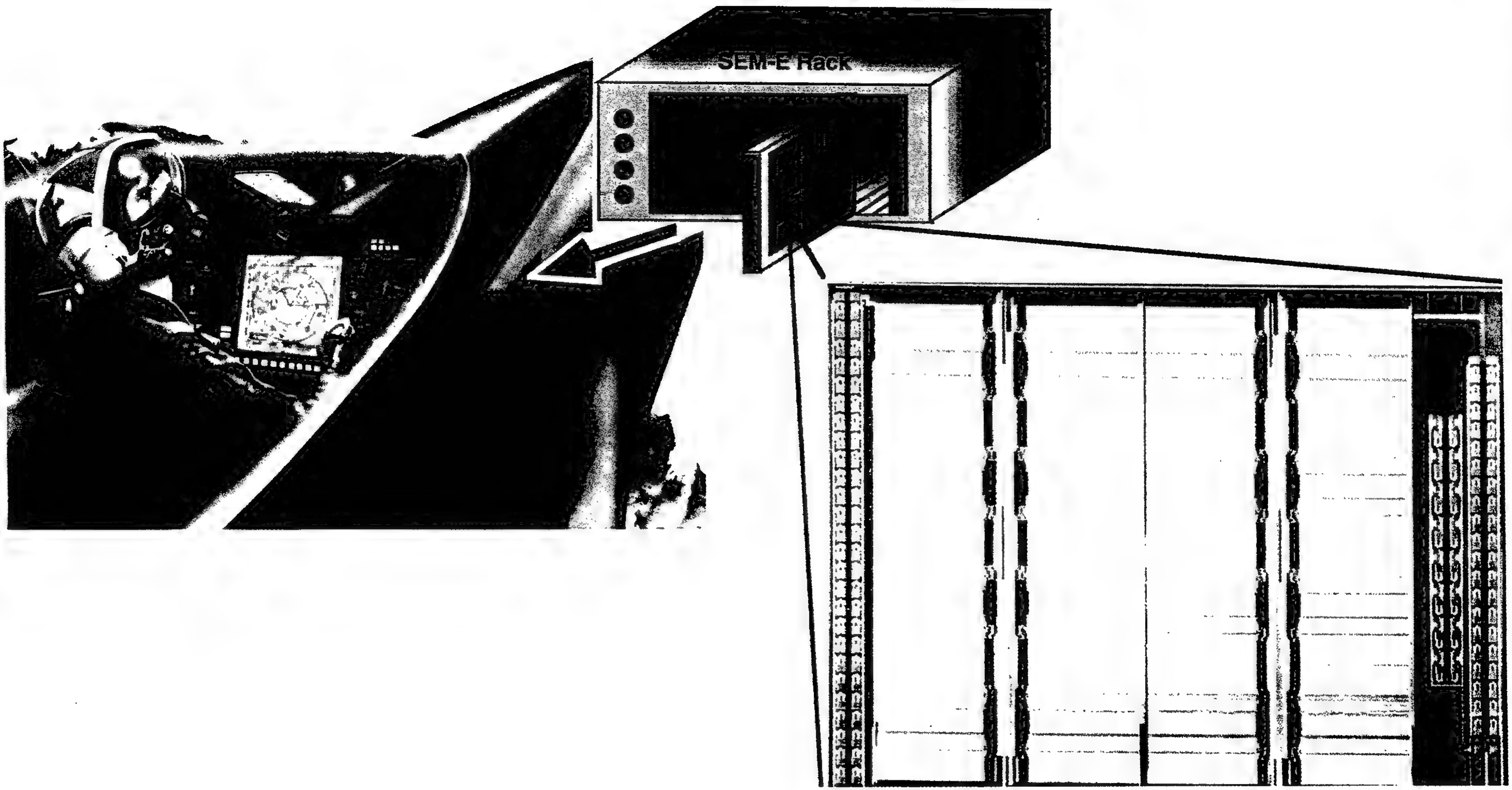
By simply depressing a switch with his thumb and pointing, a crew-serve weapons operator can quickly light up an area with little or no disruption to other tasks he is performing during a rescue operation. The laser spotlight is useful in illuminating terrain features and objects hidden by shadows, which are not fully discernable by unaided night vision equipment. A Cooperative Research and Development Agreement (CRDA) between the Air Force and the Night Vision Equipment Co. of Emmaus PA, will result in spin-off applications.

Accomplishment

A finger-mounted laser spotlight developed by engineers in the Avionics Directorate and used in Operation Desert Storm is the subject of a partnership which shares Air Force funded research and development with private industry. Signed in November 1992, the CRDA between the Air Force and the Night Vision Equipment Co. of Emmaus PA provides night vision equipment with the specifications needed to construct the device for use by government and the private sector.

Background

The Avionics Directorate developed the finger-mounted laser spotlight at the request of a helicopter pilot who was flying combat search and rescue missions in Desert Storm. The pilot commented that the laser spotlight was useful in illuminating terrain features and objects hidden by shadows, which were not fully discernible by unaided night vision equipment. Primarily for use in the terminal phases of operations, such as rescues or landings, the finger-mounted laser spotlight is designed for crew members who must have full use of their hands. It is capable of projecting up to a 10 foot wide laser beam as far as 300 feet without allowing the enemy to see what is being illuminated. Aside from identifying objects, landing zones and downed airmen, the finger-mounted spotlight has spin-off applications. For example, combat control teams could use the device while preparing austere landing areas at night. Potential commercial applications also exist in law enforcement and security; for instance, to search darkened buildings without giving away one's position.


SEM-E Rack

Advanced 0.35μm Integrated Circuit for Massively Parallel Processing (MPP)

Payoff

Future combat aircraft will have integrated electronics systems that combine sensor, vehicle state and mission data into a complete information environment. An advanced silicon integrated circuit with 0.35 micron features will enable extremely fast rendering of three dimensional (3D) computer graphics in a module size form factor suitable for incorporation into next generation cockpit systems. This next generation technology integrated circuit (IC) may also be programmed to perform non-graphics functions, such as best course determination, electromagnetic wave propagation, image analysis, finite element analysis and linear programming.

Accomplishment

The Solid State Electronics Directorate's Microelectronics Division has designed and built a single IC MPP for real time 3D computer graphics rendering that is small enough to be incorporated into combat aircraft and capable of the extremely low latency requirements of high speed flight missions. The MPP chip is the world's highest complexity (3.5 million transistors) digital logic IC using less that half-micron features, and was the design used that set the world's record in IC manufacturing cycle time (70 hours).

Background

Future combat aircraft will have integrated electronics systems that combine sensor, vehicle state and mission data into a complete information environment. This integrated information environment maximizes pilot's situational awareness by providing a computer generated synthetic audio-visual cockpit interface. The cockpit interface is based on multiple real-time, visually realistic, computer graphics displays. Current technology simulator and workstation display systems are either too large or too slow to permit their use in a modular integrated avionics suite. The MPP chip enables the required performance attributes to be packaged in a multi-chip-module form factor and provides the basis of the cockpit graphics subsystem. The MPP's superior performance density is achieved by use of the next generation silicon IC fabrication capabilities, high clock speeds and a massively parallel architecture. The advanced IC fabrication was conducted as part of the Wright Laboratory/ ARPA Microelectronics Manufacturing Science and Technology (MMST) program managed by the Solid State Electronics Directorate. The MPP's 10 nanosecond cycle time is comparable to that of the latest microprocessors that will be in the next generation avionics systems. The massively parallel architecture is a synthesis and extension of Avionics Directorate funded research conducted by Honeywell Inc., ARPA funded research conducted by the University of North Carolina and other bit-serial single instruction multiple data (SIMD) computers such as those developed by Goodyear Aerospace Inc., Martin-Marrietta Inc., Thinking Machines Inc. and Wavetracer Inc. A design team of the Microelectronics Division used concurrent engineering to develop and model a significantly improved architecture and a full built-in test capability, while building the silicon design environment from scratch. The team designed the 3.5 million transistor IC in only one year, proving the value of the integrated top-down IC engineering methods the Solid State Electronics Directorate continues to pioneer.

Development, Patent of Automated Composite Curing Process Earns Royalty Dividends

Payoff

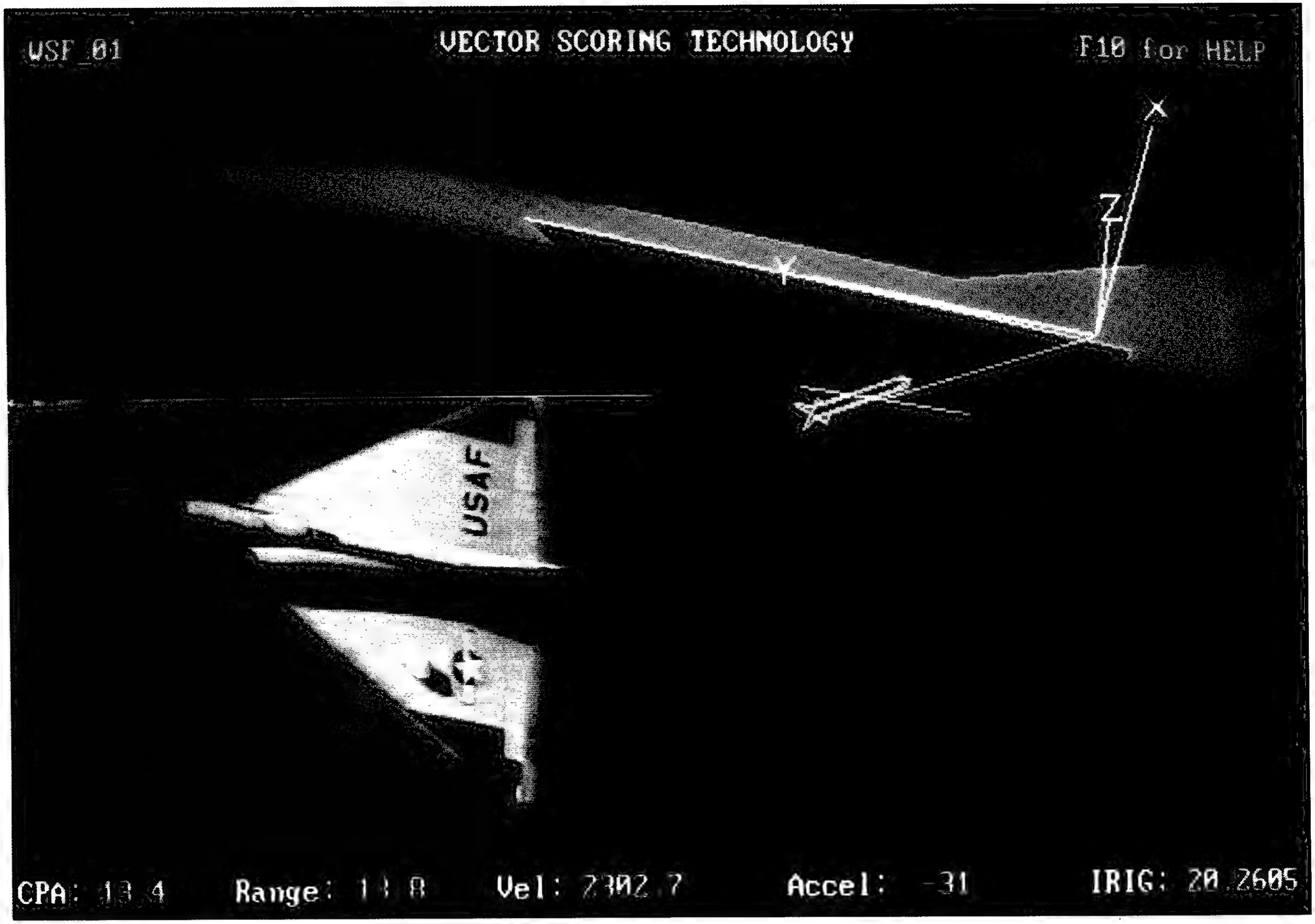
Transferring qualitative process automation (QPA) technology to private industry has yielded an initial monetary return to the Air Force for its research and development investment. Commercial availability of a software code called qualitative process automation language (QPAL) enables industry to reap the benefits of its use and ensures that it is available and supported by a commercial vendor for use on other Air Force programs. It is expected to save the Air Force $5 million per year for wide spread application to the processing of composite components. Shown on the left is a composite autoclave with a QPA monitor.

Accomplishment

The Air Force received its first royalty payment from a commercially marketed automated composite curing process developed and patented by researchers at the Materials Directorate. Lawrence Associates, Inc. (LAI), of Dayton OH, a licensee of the patent, presented the Air Force with a check for $1,300 for the first royalty payment from sales under the license agreement.

Background

Materials Directorate scientists and engineers have developed and patented a new process for the autoclave curing of composite materials. Referred to as QPA, it focuses on process quality via computer controlled sensors that assess material behavior during the curing process and adjusts process parameters based on events measured by the sensors. The computer controls the process using a software code called QPAL. Prior to QPAL's development, autoclave curing of composites was accomplished using a prescheduled temperature and pressure method which required constant human intervention to assure optimum product quality. QPAL provides the means to automate the process by incorporating an expert's knowledge of materials, process and control technology. Processing time has been reduced by 70 percent using the QPA technology. LAI acquired a license from the Air Force to exploit the technology. LAI refined the QPAL code for industrial applications and is marketing the software as a commercial product. They are also exploring the software's use for a much broader range of applications that are suited to event-driven control. The $1,300 royalty check, presented to Dr. Vincent Russo, director of the Materials Directorate on June 10, 1993, represents the first royalty payment to the Air Force from QPAL's growing commercial sales.



USF_01
VECTOR SCORING TECHNOLOGY
F10 for HELP
X
Y
Z
USAF
CPA:
Range:
Vel: 2302.7
Accel: -31
IRIG: 20.2605

Non-Cooperative Vector Scoring System

Payoff

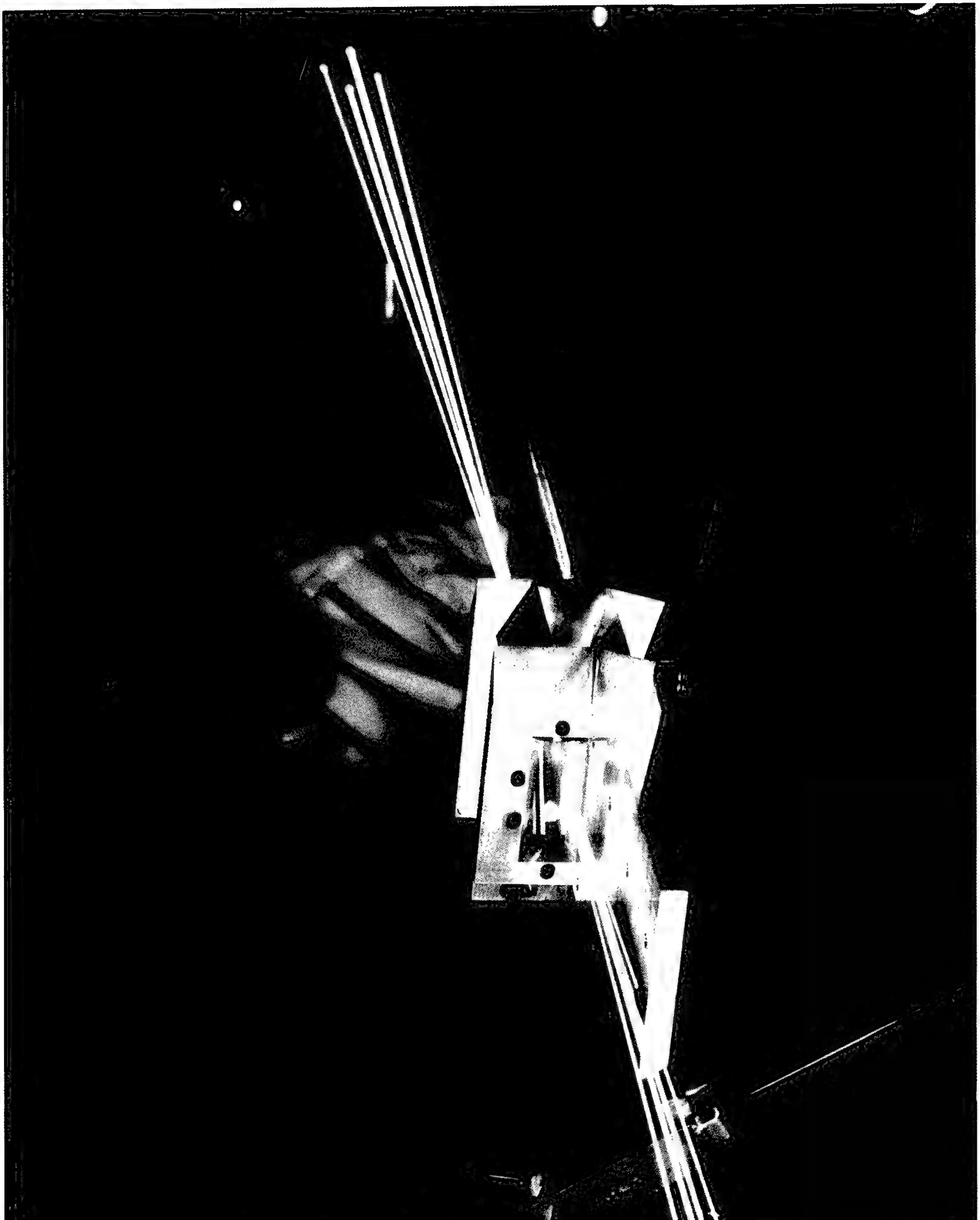
Since pilots during weapon training do not always see where the missiles hit the target, they utilize the non-cooperative vector scoring to obtain this information. The aircraft in the top of the photo on the left is a computer generated score. This is compared to the actual photo of the QF-106 drone (lower left) which shows the missile coming through the left wing at the same location. Called the Non-Cooperative Vector Scoring System, this new electronic scoring system provides more information faster, at less cost than present target scoring systems, and does not require modifications to the missile. By not having to modify missiles, estimated savings of $18 million over 5 years will be achieved. Additional cost savings will be obtained through the reduction of ground support equipment required for end game miss distance verification.

Accomplishment

The Armament Directorate's Instrumentation Technology Branch developed a non-cooperative vector scoring system that enables a pilot to ascertain within minutes after firing a missile whether or not it has engaged its target. In a weapon engagement against a QF-106 drone, the non-cooperative vector scoring system provided a scalar (miss distance) score within one minute after missile intercept and the vector angle in an hour. Aircrews can now have the results of a missile shot the same day compared to the present two-week turn-around time.

Background

This Vector scoring system originally was designed to support the Air Force's Weapon System Evaluation Program (WSEP), a USAF Air Warfare Center Program that provides aircrews a rare opportunity to fire a live weapon at a maneuvering drone. Unlike many scoring systems already in use, this system requires no modification to the missile fired at the drone. Older systems replace the missile warhead with an expensive electronics package, but in non-cooperative vector scoring the drone is fitted with an electronics package and five antennas strategically placed on the drone's surface. This technology uses inverse synthetic aperture radar that broadcasts a radio frequency signal and compares radio frequency transmitted and received as a three-dimensional array of ideal waveforms. The system derives the vector miss distance, acceleration, and the missile's attitude at the closest point of approach and anywhere in a 140 foot radius around the drone. Miss distances can be provided within 6 inches, and the missile attitude within 5 degrees. This technology is the only scoring system that can provide weapon analysts actual results from live warheads for fragmentation patterns. Non-cooperative vector scoring technology also quickly pro-cesses its data using a modified 486 computer. It also can be used to provide scoring for air-to-ground targets. The non-cooperative vector scoring technology is a joint Air Force/Navy development.



Laser Velocimetry (LV) Measurements for Computational Fluid Dynamics (CFD) Code Validation

Payoff

The laser velocimetry (LV) measurement set-up shown left in a MACH 6 wind tunnel is used to measure velocities of small particles within flowfields about a complex hypersonic model geometry. For high speed, complex flows, the ability to collect and analyze LV data provides for a rapid collection of large amounts of nonintrusive velocity measurements which was not previously possible. This technology will save government and private sector aerospace research organizations considerable time and money in their efforts to understand the physics of complex, aerodynamic flows associated with supersonic and hypersonic vehicles.

Accomplishment

The Flight Dynamics Directorate's Aeromechanics Division accomplished the first ever application of LV measurements for computational fluid dynamics (CFD) validation in a complex, hypersonic flowfield. This accomplishment is unique in that the collected data represents the most complex hypersonic model geometry known to have been examined by a nonintrusive technique. The experimental LV measurement bias for a practical aerospace vehicle is nearly eliminated by a systematic data reduction technique that has been developed from a series of simple model geometries. Accurate and advanced simulation capability for a high performance air vehicle can be established by the combined experimental and CFD technologies.

Background

Nonintrusive flowfield diagnostics provide actual experimental measurements of less total quantity then the simulated CFD representation, but computational solutions require assumptions and constitutive models (not based on physics) which must be experimentally validated. LV is a technique which uses laser beams to nonintrusively measure velocities of small particles entrained within aerodynamic flowfields. If the measured velocity of a particle represents the flowfield velocity, it can be used for direct comparison with computational flowfield predictions. However, in high speed, complex flows, this is rarely the case. Particles rely on aerodynamic drag to move them with the flow, but this force can be small in relation to the particle inertia. Consequently, for high speed velocity measurements, previous data sets could only be compared qualitatively with CFD predictions since the measurement bias could not be determined. The Aeromechanics Division, a recognized leader in the ability to collect LV measurements in high speed flows, developed an extensive technique to couple CFD with experiments in order to quantify the difference between the particle and flowfield velocities. This breakthrough greatly enhances the ability to validate CFD predictions in this regime and puts the Flight Dynamics Directorate at the forefront of this technology.

Working For DOD and The Electronics Industry

FORMAL VERIFICATION

SYNTHESIS

DEBUGGING

COMPILATION

DESIGN ENTRY

VHDL

FIPS PUB. 172

ANSI/IEEE - 1076

AF POLICY 92M-017

HARDWARE ACCELERATION

DOCUMENTATION

SPECIFICATION

SIMULATION

Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL)

Payoff

Computer assessment of electronic designs before construction is critical in modern complex, tightly coupled systems. Use of the very high speed integrated circuit (VHSIC) hardware description language (VHDL) in the F-22 program to document and simulate interfaces between critical system components and by Air Force Air Logistics Centers in reengineering and redesign of systems with obsolete parts will yield a savings of several billion dollars over the next ten years.

Accomplishment

The Solid State Electronics Directorate aided Headquarters Air Force Materiel Command (HQ AFMC) in the application of VHDL to the F-22 aircraft, the Computer Aided Acquisition and Logistics Support (CALS) program, and reengineering and replacement of systems. The successful use of the VHDL technology by the F-22 and other Air Force and DOD programs, have led to VHDL being established as a federal information processing standard (FIPS) required by all Federal Agencies under FIPS Publication 172.

Background

Documentation of complex electronic systems has been a very difficult problem. As systems have become more complex and more tightly integrated, development of designs that are error free is extremely difficult. Tightly coupled systems also means that complex design information must be shared across many geographically diverse companies. In modern systems, many different contractors must share design data. An error in any place could result in disastrous results in electronically controlled aircraft. The Solid State Electronics Directorate recommended the use of VHDL to aid in communicating design information across contract boundaries as well as documenting the design of the finished product. VHDL provides a simulation model of the electronic system and makes it much less likely that design errors will propagate. In the F-22 program all critical interface specifications are being modeled and circulated to all contractors. Because the information is in the form of a simulation model, no misunderstanding or misinterpretation of a specification is likely. In this way critical design information is being passed between over twenty contractors. The Solid State Electronics Directorate support of HQ AFMC resulted in the formulation of Air Force Acquisition Policy 92M-017, recommending that VHDL be used on all Air Force Programs. Under the DOD CALS program, the Solid State Electronics Directorate is supporting HQ AFMC to institutionalize VHDL technology in all Air Force Air Logistic Command's and Army/Navy engineering support activities.

Integrated Data Strategy (IDS) Saves Engineers Time, Money

Payoff

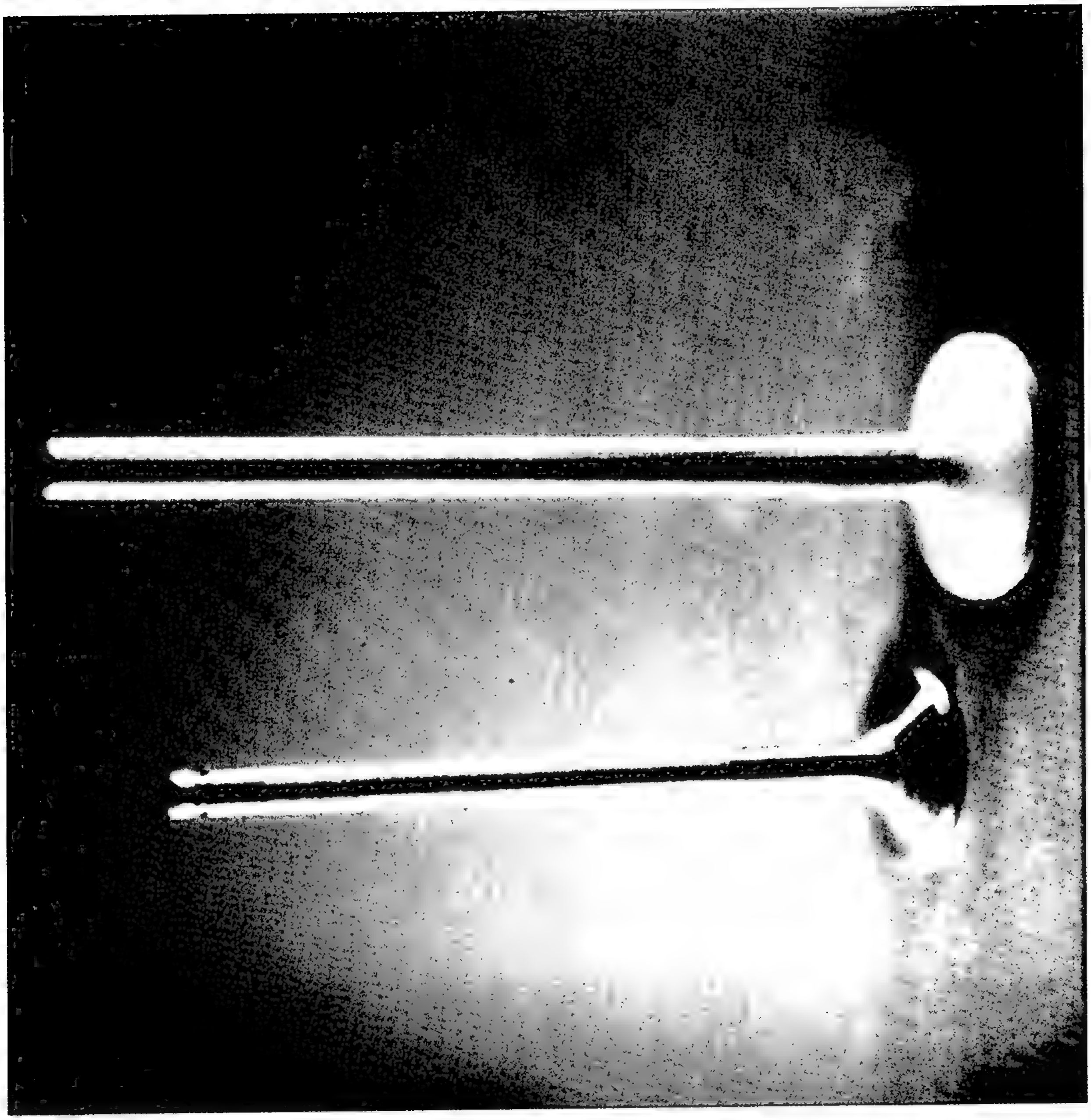
Compared with the manual process of acquiring data, engineers, like the one shown left designing a B-1B battery tray guide, can use integrated data strategy (IDS) to conserve more than 40 percent of their time that is wasted in searching for data from paper drawings and libraries. Implementation of IDS at all Air Logistic Centers will eliminate paperwork and allow engineers and manufacturing designers to work more effectively. Prototypes will also be installed at Navy facilities at Johnstown, PA and Cherry Point, NC.

Accomplishment

The Manufacturing Technology Directorate, in conjunction with the Armstrong Laboratory's Human Resources Directorate and the Air Force Computer-Aided Acquisition and Logistics Support (CALS) office, have developed a prototype of an integrated weapon system database which eliminates paperwork and makes Air Force Materiel Command Air Logistics Center engineers' tasks easier. The IDS prototype serves as a single source for engineering, manufacturing, logistics and technical information. It was used in-house to redesign a component of the B-1 landing gear, resulting in savings of more than $150,000.

Background

Massive amounts of today's technical data resides on paper or in electronic databases accessible only from specific computers. This makes management, sharing, and configuration control of critical information difficult, time consuming and expensive. A solution to this problem is being developed as part of the CALS initiative. An important step of CALS is the IDS. IDS provides engineers access to digital information using their computers to reduce time wasted in searching for data from paper drawings and libraries. The Air Force conducted three successful demonstrations of this prototype. The initial demonstration showed how to tap into engineering and manufacturing data. This effort used a variety of hardware and operating systems and incorporated three separate databases in Arizona and California. The other two IDS demonstrations were performed in conjunction with Oklahoma City-Air Logistics Center (OC-ALC), Tinker AFB OK. These demonstrations focused on comparing old manual processes with the new automated process, using actual aircraft modification scenarios and aircraft data. One demonstration used IDS with data from local computers to redesign a B-1B battery tray guide, then manufactured the redesigned part on the center's numerically controlled machining facilities. The latest demonstration added selected commercially available technologies to the existing OC-ALC systems with which engineers designed and analyzed a safety modification to the KC-135 strobe light. The prototype system was also used to resolve a problem concerning cracks in the bellcrank component in the B-1 landing gear.



New Metal Alloy Has Military and Commercial Applications

Payoff

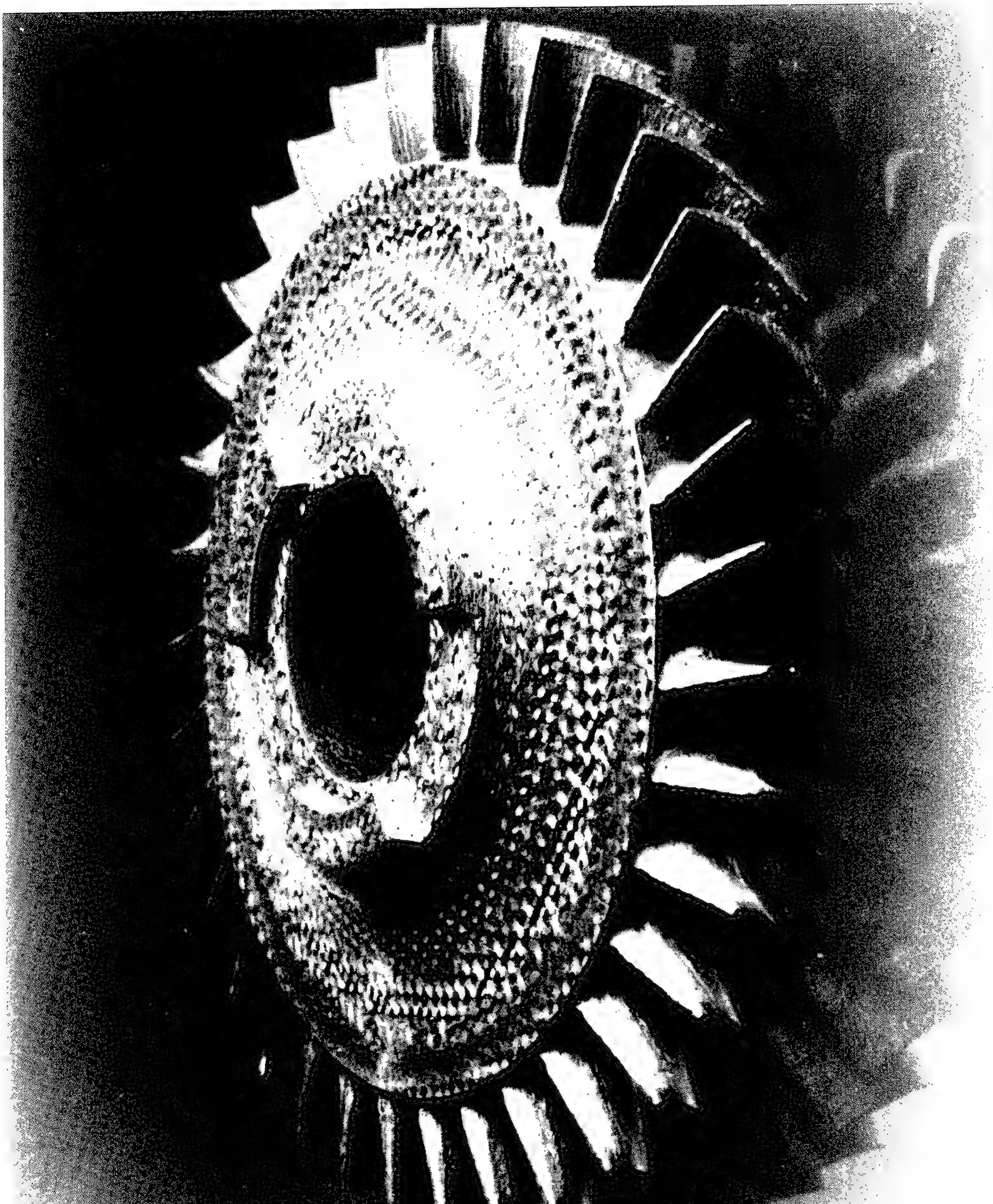
A finished titanium aluminide (TiAl) alloy exhaust valve for a high performance V8 automobile engine is shown on the left (background). Use of the alloy, which was developed for use in aircraft turbine engines, in automobile engines will increase engine power, fuel economy and response to rapid load changes. TiAl alloy components are being considered for the F-22's upgraded F-119 engine.

Accomplishment

The Materials Directorate's Metals and Ceramics Division developed a new gamma TiAl alloy for use as a high strength, high temperature (650 - 925°C), aerospace structural material. The alloy's combined properties of high strength at high temperature, low weight and resistance to burning and oxidation required for aircraft turbine engines also make it well suited for use as automotive engine valves and turbocharger rotors.

Background

Engineers and scientists from the Directorate's Metals and Ceramics Division are working with General Electric Aircraft Engines, General Motors' Allison Division, and Pratt and Whitney to transition the technology into military and commercial turbine engines. This new alloy will replace heavier and more expensive nickel based superalloy metals used in aircraft turbine engines and other high temperature, high performance applications. Their TiAl alloy and processing technologies are also being transferred to Ford, General Motors and TRW to increase automobile engine power and fuel economy. To help transfer the technology, the processing techniques are being tailored for use with existing automotive industry machines suited for high volume, low cost production. Components made from the alloy have lower weight and inertia. The reduced weight and inertia enable up to 10 percent higher engine speeds (revolutions per minute) and accompanying power output coupled with quicker response to load changes. The alloy's high temperature burn and oxidation resistance permit higher operating temperatures that increase efficiency and fuel economy. Manufacturers of commercial turbines used to power land-based electric utility generators are also considering using the alloy.



Government, Industry Consortium to Improve High Temperature Composite Materials

Payoff

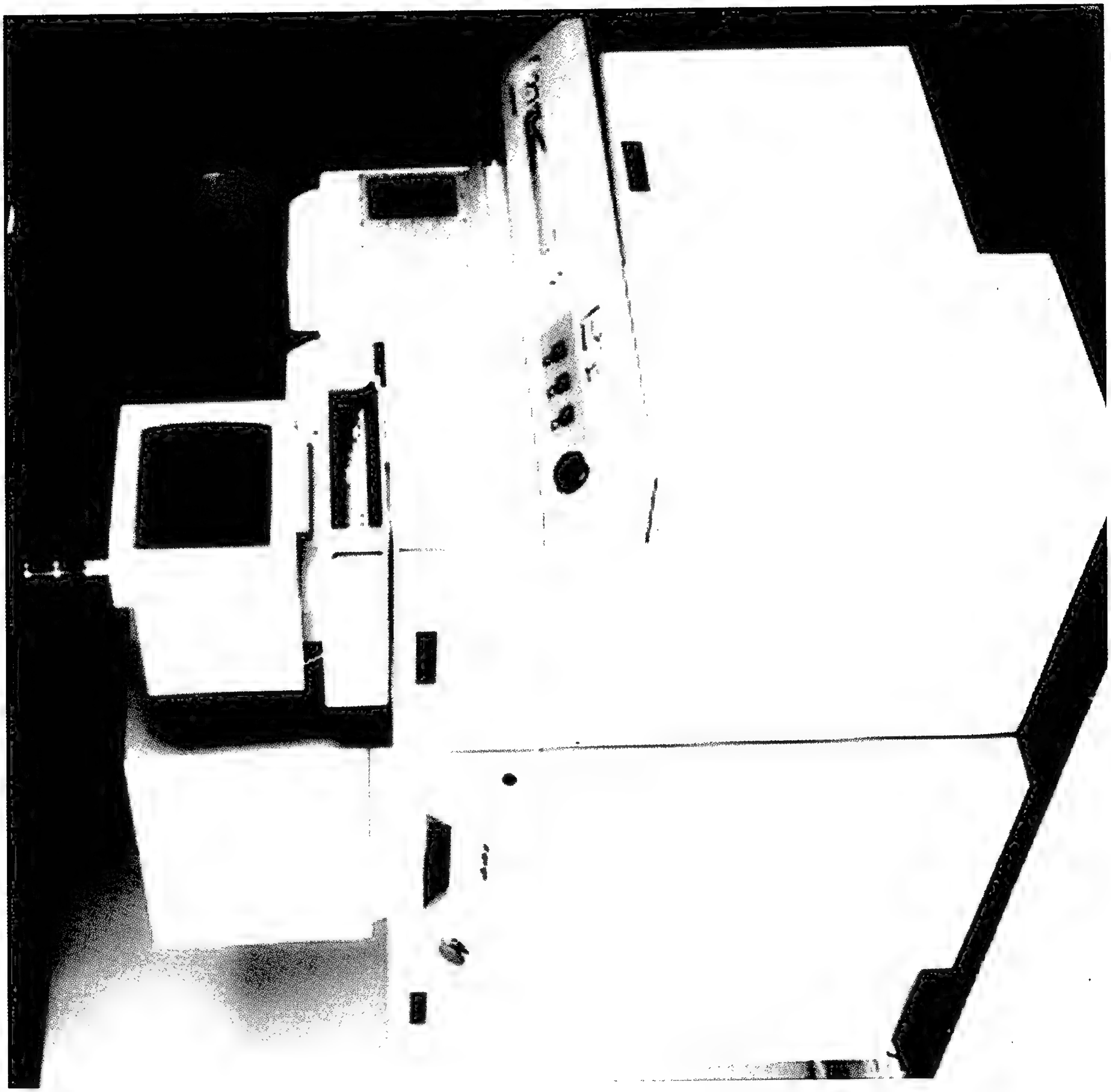
The consortium represents a new approach to research that combines the technical expertise of government and industry to focus on a common objective. Spearheaded by the Materials Directorate, its efforts to develop ceramic fibers as reinforcing constituents in high temperature composite components, like the ceramic matrix composite experimental bladed rotor shown on the left, will result in sources for high performance ceramic fibers that will meet future gas turbine engine composite material needs.

Accomplishment

The Materials Directorate has spearheaded formation of an industry and government consortium to develop ceramic fibers for use in high temperature ceramic and metal matrix composites. Seven Integrated High Performance Turbine Engine Technology (IHPTET) prime contractors and the United States Government signed an "Agreement" in September 1992 to develop ceramic fibers to meet IHPTET ceramic and metal matrix composite needs.

Background

The joint DOD/NASA initiative (IHPTET) has the goal of doubling the propulsion capability of gas turbine engines shortly after the turn of the century. Seven gas turbine propulsion engine companies (Allison Gas Turbine Division of General Motors, Allied-Signal Engines (formerly Garrett Engine Division of Allied-Signal), General Electric Aircraft Engines, United Technologies' Pratt & Whitney, Teledyne Ryan Aeronautical TCAE Turbine Engine Products, Lycoming Division of Textron and Williams International) are prime contractors for the IHPTET program. High temperature ceramic and metal matrix composite materials are critical to the achievement of the IHPTET goal. The Materials Directorate is leading the development of these new composite materials which use high performance ceramic fibers as reinforcing constituents. These new composites must have sources of strong, high quality, affordable ceramic fibers for mass produced engines to benefit from the superior combinations of mechanical and physical properties the composite materials offer. The Air Force, Advanced Research Projects Agency (ARPA) and NASA are contributing funds along with each of the engine companies. The Army and Navy have been active participants for technical planning. The fiber development will be performed by parties in the materials community (not consortium members). Initial contracts have been awarded to four industrial firms, three universities and one research institute as a result of an open solicitation. It is expected that one or more new fibers will be developed and ready for manufacturing scale-up in three to five years.



Automated Manufacturing Process Lowers Integrated Circuit Costs

Payoff

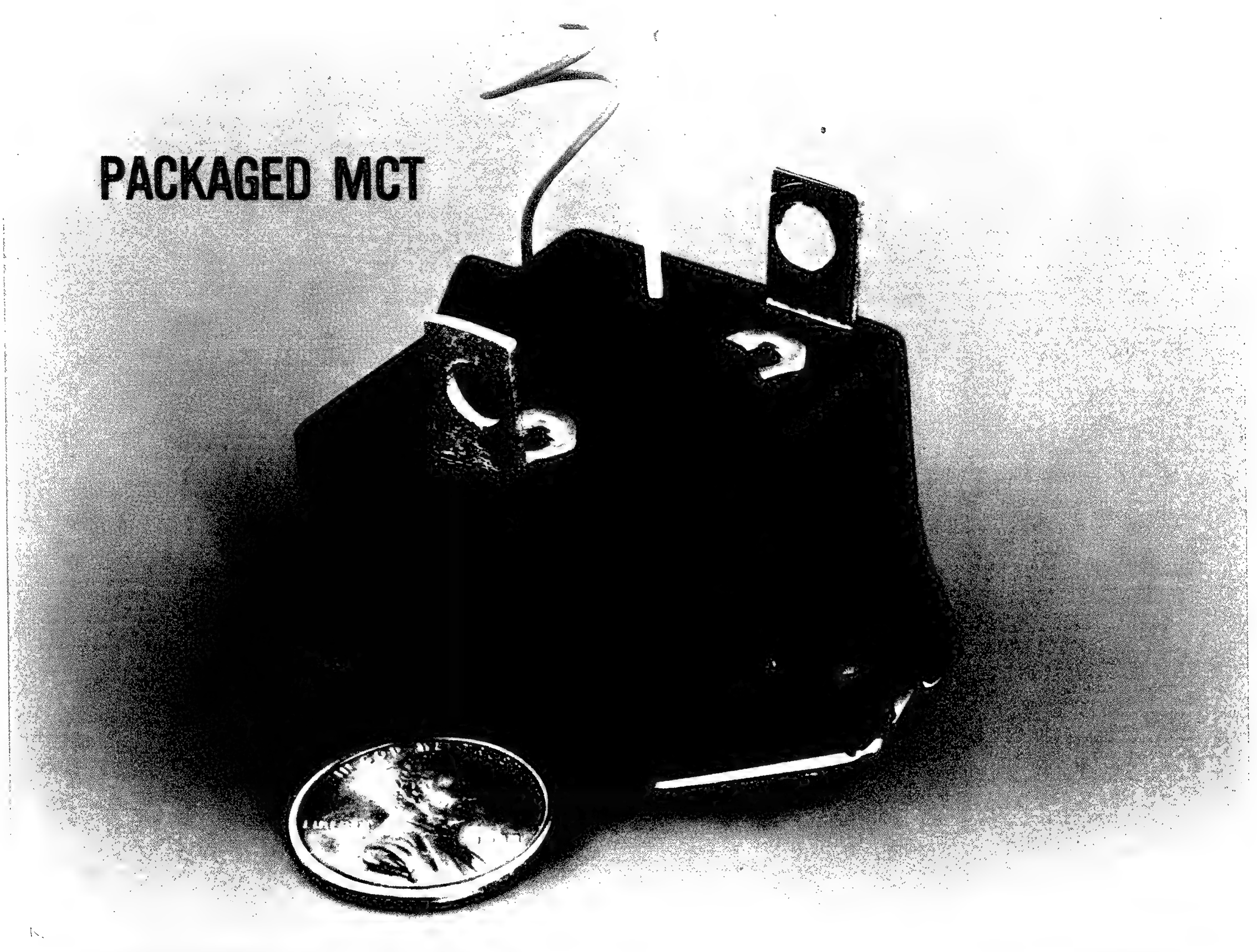
Flexible, automated, integrated circuit manufacturing techniques will provide a three-day cycle time for single-wafer lots, factory capacity at 800 wafers per month, flexibility for many designs, and modularity for easy upgrade and maintenance. These techniques are scalable to large volumes of wafers and are applicable to commercial products. Equipment, that will include cluster tools like the one shown on the left, for a minimal factory will cost $30 million compared to today's $500 million mega factories.

Accomplishment

The Manufacturing Technology and Solid State Electronics Directorates, in conjunction with Advanced Research Projects Agency (ARPA), have developed automated flexible manufacturing techniques that will lower the cost of semiconductors used by the military. By using these techniques, semiconductor manufacturers can lower factory costs, reduce cycle times for small lots, increase yields and provide flexibility for many concurrent designs.

Background

Commercial semiconductor process lines are tailored for high volume manufacturing. Each fabrication line is dedicated to producing large volumes of a single device type. The process lines are kept full and processes continually adjusted to keep yields high. In contrast to the demand for commercial semiconductors, the typical military requirement is for low volume specialty devices. Unique demands make military orders for semiconductors difficult to produce on conventional commercial processing lines. Because of these limitations, military semiconductors are very expensive and require long lead times (2-3 months or more). To reduce the cost of military semiconductors, new, creative and cost-effective manufacturing methods needed to be developed. Researchers from Texas Instruments Inc. of Dallas TX, working under contract with the Wright Laboratory/ ARPA team, have started down the path towards solving this problem by developing a fully integrated, modular cluster tool facility for the processing of application specific integrated circuits (ASICs). Wafers are processed in single-wafer modules, with real-time computer process control, optimized routing for minimal wafer handling, and automated factory planning and scheduling. Wafers are transported by a vacuum carrier that provides a clean room environment. Processes use dry techniques, such as plasma etch, chemical vapor deposition and dry development. An important part of the facility is the computer integrated manufacturing object-oriented factory control system, a system which encompasses the planning, scheduling, process control, process specification, equipment interface, system services and user interface subsystems. As a factory control system, it integrates all cluster tools along with other factory equipment.


PACKAGED MCT

METAL OXIDE SEMICONDUCTOR (MOS) CONTROLLED THYRISTOR (MCT) - R&D 100 AWARD

Payoff

Identified by R&D Magazine as one of the 100 most technologically significant products of 1993, the metal oxide semiconductor (MOS) controlled thyristor (MCT) has been successfully transferred to the commercial sector (as illustrated on the left). It is a pervasive and enabling technology for the more electric aircraft (MEA). The MEA will require a significant amount of power conditioning, power control and motor drive equipment for implementation. This equipment, when compared to equipment manufactured in the late 1980's with state-of-the-art bipolar junction transistor technology, will realize a 50% weight and volume reduction and a 25% improvement in reliability by utilizing new MOS controlled devices such as the MCT.

Accomplishment

The MCT was recognized by R&D Magazine as one of the 100 most technologically significant products of 1993 and is a finalist in Electronic Design News Magazine's 1993 Innovation of the Year. The MCT is a new electrical power semiconductor switching device that, when compared to the best state-of-the-art power device — the insulated gate bipolar transistor (IGBT), offers a 50% increase in efficiency, 20% higher temperature capability, 50% higher current density capability and a 50% higher surge current capability.

Background

Since 1986, the Aero Propulsion and Power Directorate has been a major sponsor (with Air Force and Strategic Defense Initiative Office funding) in the research and development of the MCT. This sponsorship brought the MCT from a low power (<1 kW) laboratory curiosity to the development of high power devices (>100 kW) for insertion into advanced development hardware. MCTs are a new class of power semiconductor devices that combine thyristor current and voltage capability with MOS gated turn-on and turn-off. Various subclasses of MCTs can be made: P-type or N-type symmetric or asymmetric voltage blocking, and various turn-on alternatives including direct turn-on with light. All of these subclasses have one thing in common: turn-off is accomplished by turning on a highly interdigitated field effect transistor to short out one or both of the thyristor's emitter base junctions.

Cockpit Solar Shield Design Development Receives Recognition

Payoff

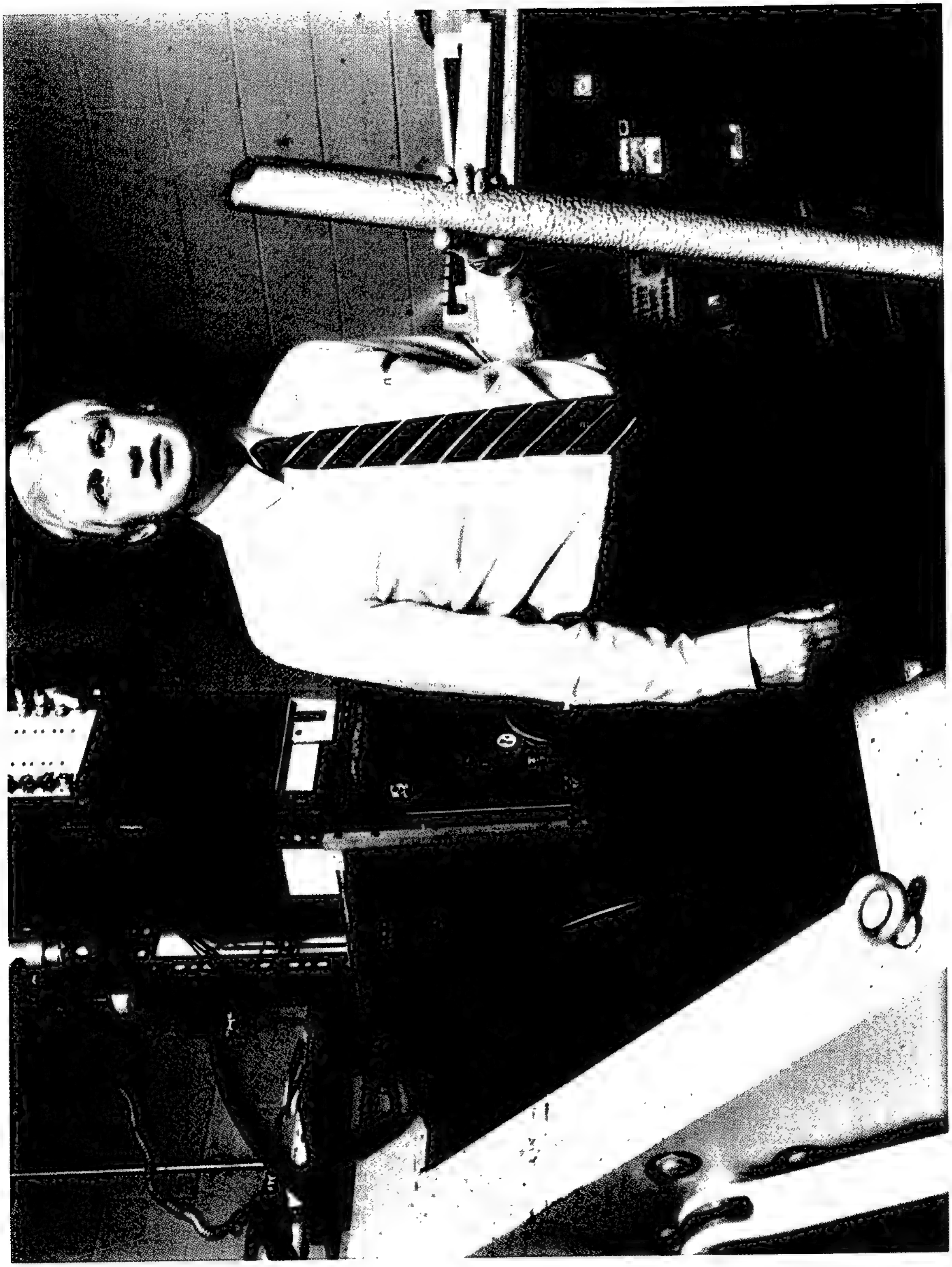
Mr. Malcolm Kelley received the 1992 Air Force Science and Engineering Award for his work on cockpit solar shield design development. Cockpit air temperature reductions of 60 to 80 degrees, achieved through the employment of solar shields, will produce tolerable working conditions for aircrew and maintenance personnel, significantly increase service lives for cockpit equipment and improve operational readiness. Estimates indicate annual savings from solar shield use will be over 400 million dollars.

Accomplishment

Mr. Malcolm Kelley of the Flight Dynamics Directorate's Vehicle Subsystems Division received the 1992 Air Force Science and Engineering Award from Dr. George R. Abrahamson, Chief Scientist of the Air Force, for his work on cockpit solar shield design development. To date, cockpit solar shield designs for 70 different DOD aircraft, plus 20 designs for allied military aircraft have been developed. Test and operational evaluations have shown the shields to be easy to use, durable, and popular with maintenance and aircrew personnel.

Background

Cockpit temperatures of 215 degrees F have been measured at CONUS locations, and Desert Shield conditions were even more severe. High cockpit temperatures cause numerous problems that include increased failure rates of cockpit equipment, degraded job performance of aircrew and maintenance personnel, and decreased operational readiness. In September 1990, the Vehicle Subsystem Division initiated an in-house effort to develop solutions to the hot cockpit problems. The first useable prototype solar shield for a fighter aircraft was developed in February 1991. Kennon Products Inc. of WY was later commissioned to develop and manufacture shields for all DOD aircraft and helicopters. Ninety solar shield designs have been developed to date. Most of the designs have been evaluated, and many have been tested in a wide range of climates on five continents. Operational units have found the solar shields to be not only effective in preventing hot cockpits during hot weather, but also effective in preventing condensation at night. In over 90% of operational evaluations, the initial prototype designs required no changes.



Ultra Pure Silicon Improves Infrared Sensors and Semiconductor Devices

Payoff

The ultra pure silicon (displayed as a rod shown on the left) enables improvements of up to 25 percent in very long wavelength (17 μm) infrared (IR) detector sensitivity and up to 40 percent increase in operating temperature. These improvements can result in significant enhancements of a detector's ability to "see" objects in space, in addition to reduced power consumption and satellite weight. The material also enables production of power transistors and switches with larger power handling capability for military, industrial and electric utility applications and higher density computer chips for increased computing capability.

Accomplishment

Scientists at the Materials Directorate have developed the capability to manufacture polycrystalline silicon material that is operationally free of impurities. The cost of this ultra pure silicon material was 50-80 percent lower than prevailing prices ($1000 -$3000 per kilogram) at the time of the accomplishment. Several organizations had produced small quantities of ultra high purity silicon but not with the reliability or at the price needed to support silicon semiconductor device production.

Background

Silicon semiconductor devices are the heart of many critical defense products. The performance and producibility of silicon devices are directly dependent upon the purity of the starting material. In-house research scientists from the Materials Directorate's Electromagnetic Materials and Survivability Division modeled long wavelength (15-20 μm) IR detectors and found that silicon of extremely high purity could result in substantial performance improvements of arrays used to find objects in the cold background of space. They also developed in-house technology to measure the minute traces of impurities present in the ultra pure silicon, including a laser processing method for attaching electrical contacts to the material without introducing additional impurities. A contracted program, guided by the in-house team, with Hughes Research Laboratories of Malibu CA, to develop the high performance very long wavelength infrared detectors led to a subcontractor's ability to produce large lots of polycrystalline silicon that are nearly 99.999999999 percent pure. This purity level, which represents less than 2 impurity atoms contained in each 100 billion silicon atoms, was not reliably measurable by previous techniques. The material is now commercially available (Hemlock Semiconductor, MI) as the starting material to grow silicon single crystals used to manufacture semiconductor devices.


HARD TARGET FUZE FOR GUNSHIPS

Hard Target Fuze for AC-130H Gunships

Payoff

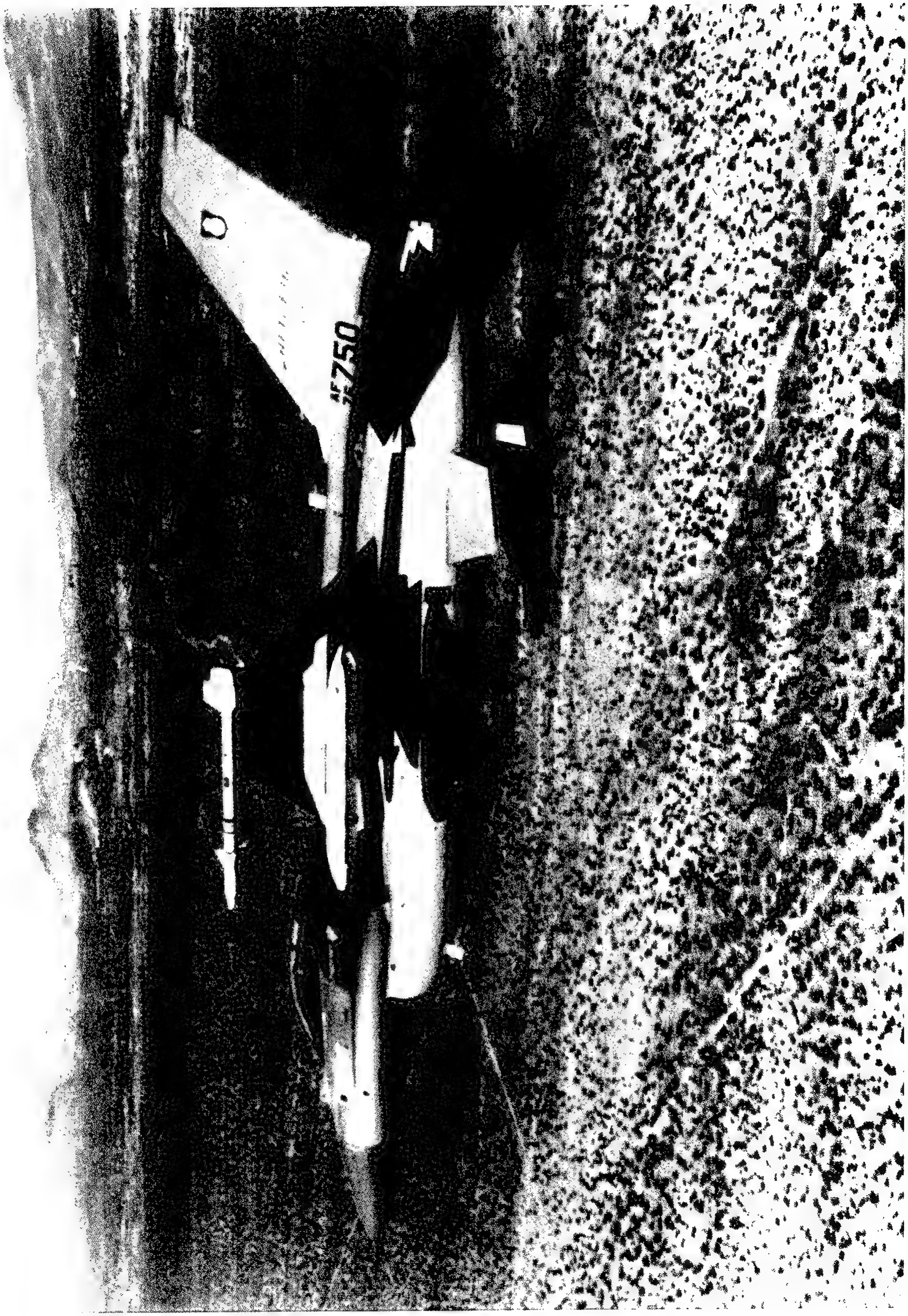
The modified hard target Mk-407 fuze for the 105mm M1 projectile used in the howitzer on Special Operations Forces (SOF) AC-130H gunships will dramatically improve hard target penetration capability. The fuze enables projectile penetration of double reinforced concrete targets at high impact angles with delayed detonation within the target.

Accomplishment

The Armament Directorate developed, fabricated and delivered 105mm M1 projectile fuzes with hard target penetration capability to the SOF Munitions Special Project Office (SPO) for immediate Gunship application without additional qualifications/ certification costs.

Background

In July 1992, Directorate personnel were briefed by Aeronautical Systems Center's (ASC) Directorate of Mission Area Planning and Headquarters Air Force Special Operations Command on the deficiencies of M-557 and Mk-407 fuzed 105 mm M1 High Explosive projectiles when fired at relatively soft targets. The M-557 and Mk-407 fuzes were designed to provide selectable super quick or delay function. The failure of the projectile to penetrate targets for delayed fuze function within the target had been noted in Grenada and Panama. The basic deficiency was projectile rupture at the fuze interface resulting in fuze breakoff or fuze submersion/ "stuffing" back into the projectile body. After review of the M1 projectile design, the Directorate's Fuze Branch recommended fuze body redesign to incorporate a protective skirt to encapsulate the projectile at the threaded interface. The modified fuze body design would allow projectile penetration and fuze function behind the target at oblique impacts as well as reduce ricochets at obliquity. A more structurally sound design would also prevent fuze "stuffing"/ dudding at all impact conditions. The SOF Munitions SPO provided funds in late 1992 for development of a hard target, anti-ricochet fuze body which would be designed with the identical internal configuration as the Mk-407 fuze body. The rationale was to use the proven safe and arm mechanism, detonators and delay feature of the Mk-407 fuze which would not need to be requalified. Fourteen modified fuze bodies with Mk-407 MOD1 fuze components installed on all-up live projectiles were successfully test fired against double reinforced 5000 psi concrete targets at high impact angles. Based on the success of these penetration tests, the SPO provided additional funds for delivery of 200 complete fuze units by July 1993.



Auto Ground Collision Avoidance System (GCAS)

Payoff

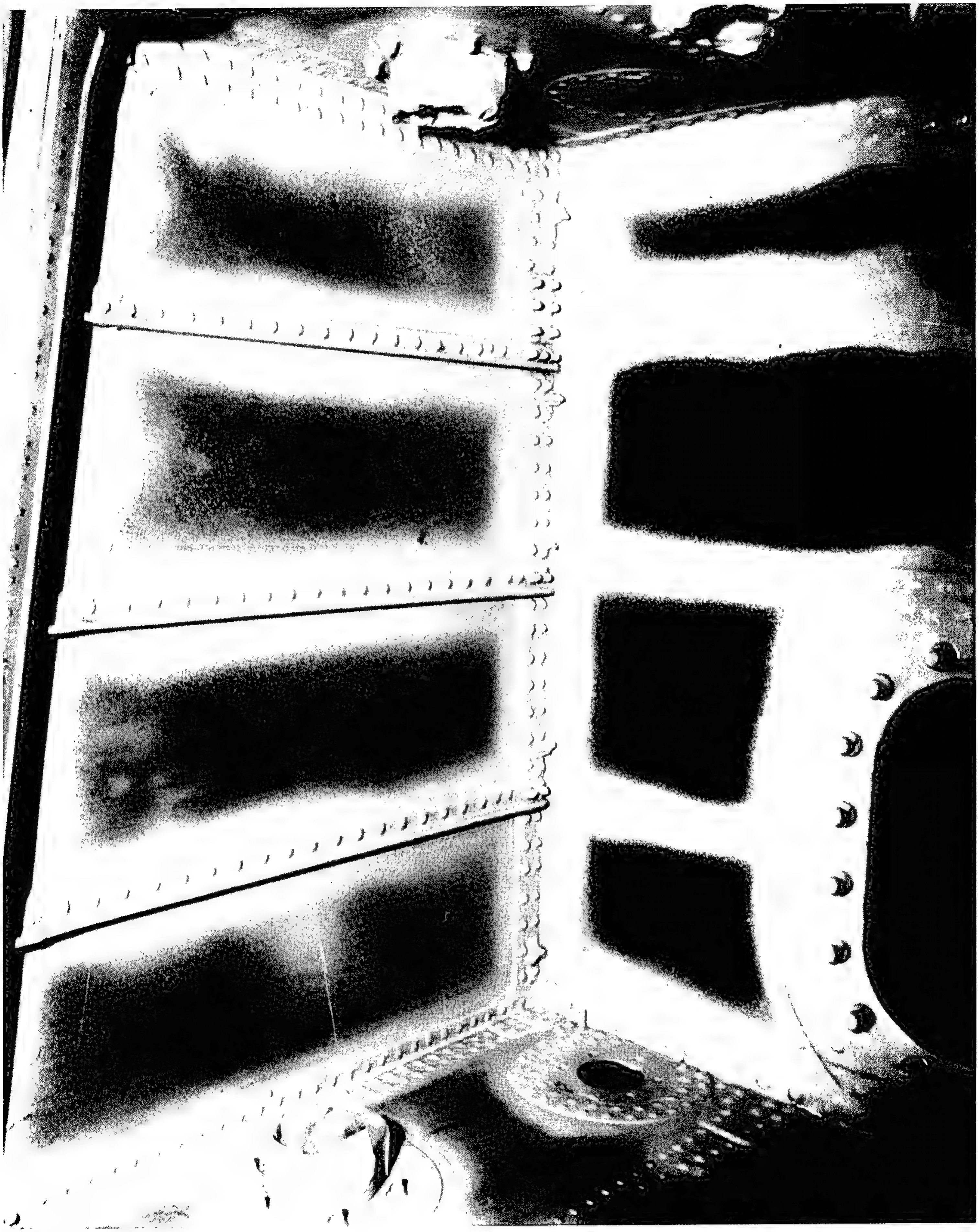
The Flight Dynamics Directorate's Advanced Fighter Technology Integration (AFTI)/F-16 Advanced Development Program Office (ADPO) and the F-16 System Program Office are developing plans to expand the auto GCAS envelope and transition it to the F-16 Block 40 and 50 aircraft. If the program is funded, the auto GCAS system could be available by late 1998 on F-16 Block 50 aircraft. The auto GCAS will prevent the loss of life and aircraft due to controlled flight into terrain (CFIT) or G-induced loss of consciousness (GLOC). The auto GCAS algorithm can be transitioned to any digital flight control equipped aircraft containing a digital terrain data base.

Accomplishment

During the close air support (CAS) phase of the AFTI/F-16 program, a limited envelope auto GCAS was successfully flight tested. The auto GCAS was shown to have the capability to save aircraft from CFIT which has been a cause of several recent fighter accidents.

Background

The AFTI/F-16 ADPO has developed an auto GCAS which uses a digital terrain system (DTS), a terrain referenced navigation (TRN) system, and a radar altimeter to determine where the aircraft is on the digital map. The GCAS algorithm continuously calculates the aircraft trajectory and if the trajectory projects a penetration of a minimum clearance distance from the terrain, chevrons appear on the heads up display (HUD) which indicate 5 seconds to flyup. The chevrons move toward each other at a rate consistent with the aircraft velocity. When they touch, they form a break X symbol and the flight control system initiates an automatic roll to wings level with a 5G flyup. If the pilot were to correct the impact trajectory prior to the chevrons touching, they would move out of view on the HUD and no auto flyup would be required. The CAS GCAS has been flight tested and was acceptable to all pilots that observed the systems operation. One of the major attributes of the system is it is always in the background and completely unobtrusive to pilot inputs. The chevrons are also an attribute because they give anticipatory events to the pilot.



Improved Fuel Tank Sealing Process for F-111

Payoff

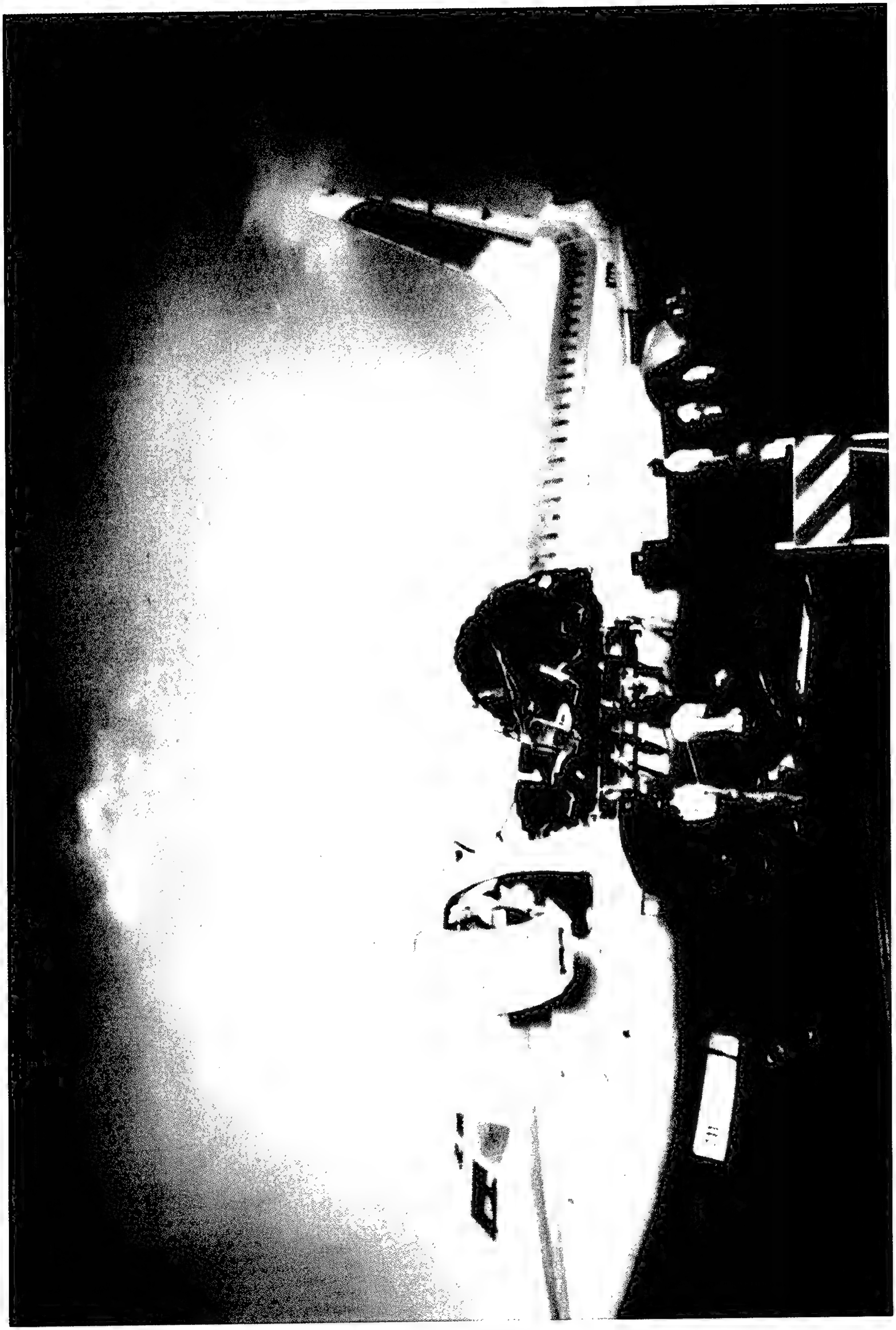
Using the improved fuel tank sealing process to apply sealant to a F-111 fuel tank will save the Sacramento Air Logistics Center (SM-ALC) $4.8 million per year in maintenance costs for the F-111 aircraft fleet. Shown on the left is a view of the inside of a tank with sprayed-on sealant areas.

Accomplishment

Engineers from the Materials Directorate, working jointly with a SM-ALC F-111 engineering team, successfully developed and implemented a faster, more effective fuel tank sealing process. This new process does not require complete removal of the old sealant and results in seals of equal or greater durability.

Background

Polyester material used to seal F-111 aircraft fuel tanks deteriorates with aircraft age and humidity requiring periodic resealing. When the polyester material deteriorates, it reverts to an acidic state and attacks other sealants and coatings. The conventional sealant replacement process requires complete removal of old sealant from the fuel tanks (desealing), hand application of an epoxy barrier to each seam of the tank, followed by hand reapplication of polyester sealant to replace the old sealant that had been removed. This process is labor intensive and time consuming. The Directorate's Systems Support Division recommended an improved sealing process to the F-111 engineering team at SM-ALC The Division worked jointly with SM-ALC personnel to develop, test and implement this improved sealing process using a polythioether/urethane sealant developed by industry. Their new process does not require complete removal of the old sealant from the fuel tanks (desealing) and resealing the tanks is accomplished with the polythioether/urethane sealant being applied with a spray gun.



Risk Analysis for Aging Aircraft

Payoff

Since the dramatic Aloha airlines incident in April 1988, where multiple site damage to a Boeing 737 aircraft occurred, aging aircraft have been a national issue. A probability of fracture (PROF) computer software program provides aircraft fleet managers with a more realistic assessment of the risk of flying, or conversely, the reliability, of aircraft structural integrity than conventional deterministic crack growth models. Inspections can be scheduled to maintain the optimum balance between risk and maintenance costs.

Accomplishment

The Flight Dynamics Directorate's Structures Division developed an analytical method to determine the risk of failure in flying aging aircraft, or a fleet of aircraft, with respect to fatigue crack growth. The computer software, PROF, was developed under contract with the University of Dayton Research Institute and is currently being used by several aircraft companies, academic institutions and government organizations. Recently the Lockheed Aeronautical Systems Company used PROF to determine the risk of flying the C-141 fleet with respect to fatigue cracking in multiple elements of the wing structure. This is particularly significant, because PROF was used as an improved replacement to their own risk analysis method due to its ease of use and accuracy.

Background

Commercial and military authorities have identified the need to fly their aircraft longer than originally intended. Of the more than 3,700 US commercial transports, one in every three is over 20 years old. In the US Air Force alone, thousands of aircraft have been in service over 20 years, and hundreds of these are experiencing service times greater than 30 years. As aircraft service lives are extended, the need to determine the risk of flying aging aircraft with respect to fatigue cracking is critical to flight safety. The PROF program provides a more realistic assessment of aircraft structural integrity than conventional deterministic crack growth models. The most notable difference is that PROF accounts for the variability in the initial fatigue quality of the aircraft structural components. PROF also accounts for variability in aircraft usage, structural inspection methods, inspection intervals, fatigue crack growth behavior and fracture toughness. Since its development, PROF has been used to determine risk of multi-element cracking in the C-141 fleet at specified wing station locations. Research jointly sponsored by the Structures Division and the Federal Aviation Administration Technical Center is currently underway to expand the capability of modeling multiple-site damage and corrosion effects in PROF.

Dual Award Winner for Contributions to Combustion Diagnostics

Payoff

The combination of experimental and modeling efforts has greatly increased the understanding of complex droplet evaporation and vapor behavior in the dense spray region of jet engine combustors. The combustion diagnostic technique developed by Lieutenant, now Captain, Robert D. Hancock of the Aero Propulsion and Power Directorate enables a detailed visualization of the location and history of the vapor as it moves away from the liquid droplet and into the carrier gas. This technique, that is critical to an improved understanding of two-phase combustion in gas turbine engines, will improve combustor design and reduce development cost.

Accomplishment

Captain Robert D. Hancock of the Aero Propulsion and Power Directorate was recipient of the annual Air Force Association Wright Memorial Chapter's Science and Technology Award and the AIAA Dayton-Cincinnati Section Outstanding Technical Contributions award. These awards were presented to Captain Hancock for the development of a revolutionary visualization technique that is a new approach to the study of two-phase combustion.

Background

In combusting flows, the flame exists where the fuel vapor and oxidant come together at stoichiometric conditions, a location that is not necessarily at the surface of the droplet. Therefore, to completely understand what is occurring in the combusting flow, the vapor behavior must be characterized. Several fundamental methods have been used to observe and analyze the behavior of the droplets and gases in complex flows. These methods, including single-particle tracks, streamlines and streaklines, provide information about the droplets and the carrier gas. However, these methods give no real consideration to the behavior of the vapor as it moves away from the surface of the droplet. The two-phase flow visualization technique invented by Captain Hancock enables detailed visualization of the location and history of the vapor as it moves away from the droplet. A computer model developed to predict the behavior of the vapor has been validated and is being exercised to learn more about the actual behavior of droplets, vapor and carrier gas in two-phase flows. A recognized expert in the field of fuel/air mixing has stated that, "The development of the visualization technique by Captain Hancock ranks as one of the few important advances in combustion diagnostics during this decade."

Better, Safer and Cheaper Binder for Propellants

Payoff

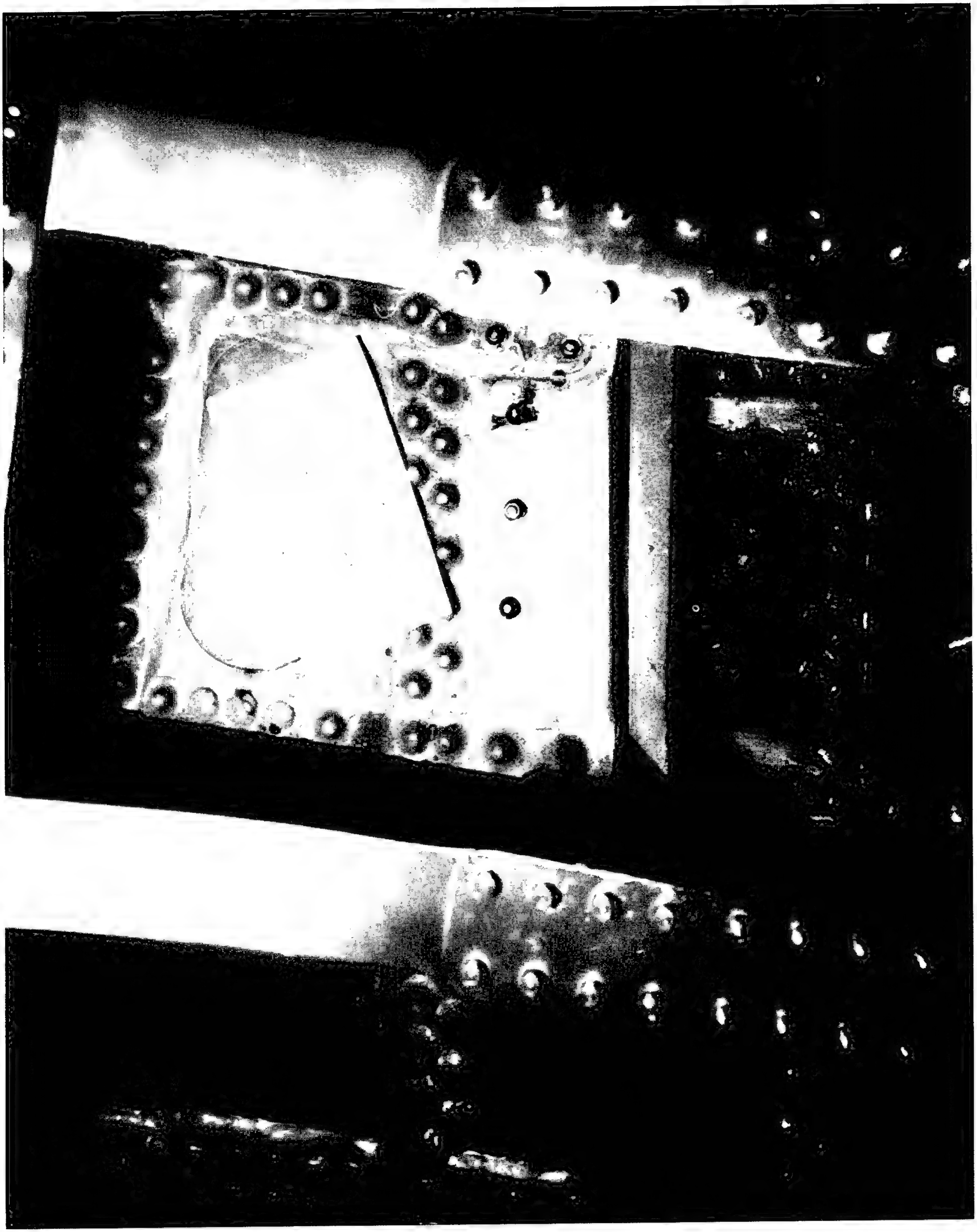
The new methyltributylammonium quaternary (MTB Quat) process will reduce the cost of propellant binder made of glycidyl azide polymer (GAP) from $80 to $15.65 per pound and will eliminate 70 percent of the hazardous waste. With the improvements in quality and lowered cost, propellant binder made of GAP will have increased utilization such as in tactical missiles to minimize signature and increase survivability.

Accomplishment

Under a program sponsored by the Manufacturing Technology Directorate, a process to produce better, safer and cheaper binder for propellants used for pyrotechnics and aircraft engine starter cartridges has been developed.

Background

Currently, propellant binder made of GAP is used for pyrotechnics and aircraft starter cartridges. Producing quality GAP is critical because it is smokeless, energetic and insensitive to shock. The current process, using dimethyl sulfoxide (DMSO) as a solvent, has a side effect of producing chemicals that cannot be recycled. Along with creating toxic waste, the DMSO process has several production problems. To produce GAP with DMSO, several runs are required because of long reaction times. The process is not cost-effective because it requires long work up, isolation steps and an added silica gel purification step needed to remove unwanted chemicals. Because of the cost and the amount of impurities left after being processed, propellants made from binder produced by DMSO have had limited use. Scientists from the 3M Corporation of St Paul MN, under sponsorship of the Manufacturing Technology Directorate, were tasked to establish a cost-effective manufacturing process to produce low cost, high quality and environmentally safe GAP. A new MTB Quat process that showed excellent consistency and met Air Force safety requirements was developed to replace the DMSO process. This process produces chemicals that can be recycled and eliminates the silica gel purification step, saving time and money.



Hazardous Material in Fuel Tank Sealants Eliminated

Payoff

The reapplication of a new less hazardous sealant inside aircraft fuel tanks, such as the one shown on the left, is currently being performed on Air Force aircraft including the F-15, F-16, C-130 and C-141. The elimination of strontium chromate as a catalyst to cure the polysulfide polymer sealant used in fuel tanks will eliminate a material from the Air Force system that is considered hazardous by the Environmental Protection Agency.

Accomplishment

Tests and analyses performed by engineers in the Materials Directorate have led to the issuance of a revised military specification for aircraft fuel tank sealants that eliminates the use of hazardous chromate compounds. A less hazardous sealant, called Type II in the specification, contains less hazardous manganese dioxide (MnO_2) as the curing catalyst instead of strontium chromate ($SrCrO_4$).

Background

One of the two types of aircraft fuel tank sealants, referred to in military specification MIL-S-8802 as Type I, has been used for many years and uses $SrCrO_4$ as a catalyst to cure the polysulfide polymer sealant. This chromate compound is considered hazardous by the Environmental Protection Agency. The similar Type II sealant contains less hazardous MnO_2 as the curing catalyst and has been used successfully since the 1970s. Use of the Type I or II sealant has usually been a matter of preference by the designer or user. Working with users, Air Force Air Logistics Centers and manufacturers, engineers from the Directorate's Systems Support Division determined there were no critical applications that required the use of only Type I sealant. They also conducted tests to ensure that the Type II sealant could be directly substituted for the Type I sealant without adverse effects. Based on their findings, an amendment to specification MIL-S-8802 was issued that deletes the Type I sealant and recommends Type II sealant as a replacement. The Type II sealant is currently being used on Air Force aircraft including the F-15, F-16, C-130, and C-141.

New Process for Applying Composite Resin Improves Composite Materials and Reduces Chemical Usage

Payoff

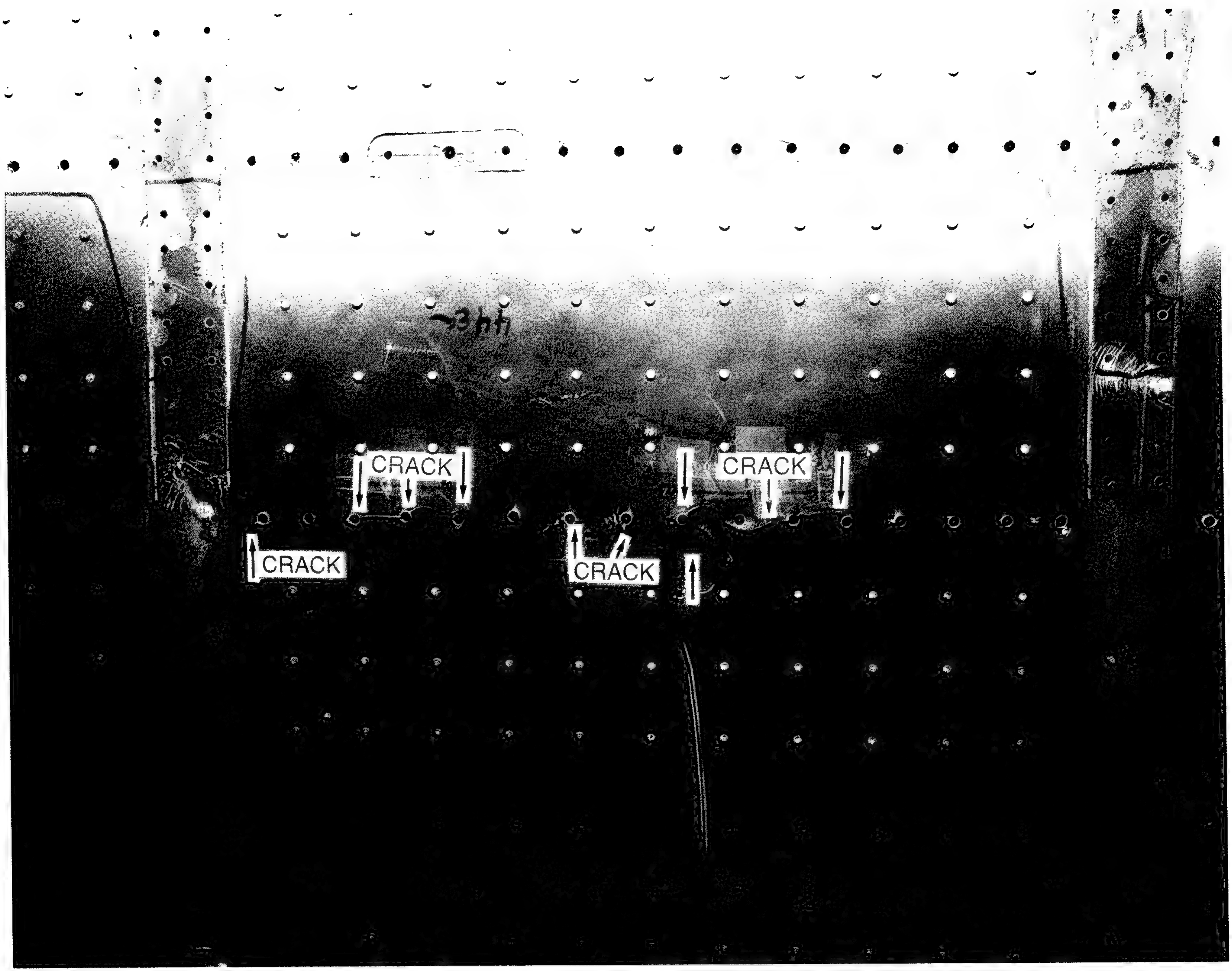
Application of the new hot-melt process for producing sheets of pre-impregnated phenolic material used to make carbon-carbon or carbon-phenolic composite components will reduce the use of hazardous chemicals in the composite production process by 75 percent, while producing improved prepreg materials at lower costs. Shown on the left is phenolic resin film prior to being hot melted into the fiber sheet to produce the prepreg.

Accomplishment

Research sponsored by Wright Laboratory's Materials Directorate has led to the application of a new hot melt process for producing sheets of pre-impregnated phenolic material used to make carbon-carbon or carbon-phenolic composite components. This hot-melt process improves the material's properties while reducing the use of hazardous chemicals from the composite production process. Prepreg produced by the new process was more uniform with double the cross-ply tensile strength.

Background

New carbon-carbon composite materials are being used for many military and civilian applications because they are lightweight and strong with high temperature stability. This composite material is produced by using sheets of fibers impregnated with a resin binder, called prepreg. Carbon-carbon components are produced by orienting these sheets to provide their desired mechanical properties, processing the stacked sheets into the desired shape and converting the shape into a carbon-carbon part. Conventional prepreg is produced by pulling fiber sheets through a bath that contains resin dissolved in a solvent and then drying the material to remove the solvent, leaving the resin within the fiber sheet. About 25 percent of the material's weight prior to drying is solvent that must be removed by evaporation. The solvent vapor is collected and incinerated to remove volatile organic compounds that are carcinogens. The new process, developed by a Science Applications International Corporation (SAIC) led team, is a hot melt process that uses much less solvent. Their process uses resin containing less than five percent solvent. Resin sheets are later placed in contact with the fiber sheets and heated, softening the resin which allows it to flow into the fiber sheets and remove excess solvent, then cooling to form sheets of prepreg. Since less solvent is added initially, the quantity that must be removed and incinerated during drying is also reduced. New process controls developed by Honeywell, Inc., Fridley MN were a key element supporting the successful demonstration of the process. Because less solvent is used, the new process can eliminate the need for workers to wear respirators during preparation of the prepreg. Sample carbon-carbon components are currently being made using the process to quantify the cost advantages of using this new process.


CRACK
CRACK
CRACK
CRACK

C-5A Upper Forward Fuselage Cracking Solution

Payoff

Acceptance of the Flight Dynamics Directorate's solution to an upper forward fuselage skin cracking problem (shown left) on the C-5A aircraft, saved the Air Force over $100 million by avoiding the retrofit of acoustically treated engine inlet cowlings that was recommended by a contractor. Further savings will be achieved as the requirement for the crack repair process is eliminated.

Accomplishment

The Flight Dynamics Directorate's Structural Dynamics Branch planned and conducted a multi-phase effort in support of the C-5 Program Office, which determined that the cause of the upper forward fuselage skin cracking on the C-5A aircraft was due to corrosion, not acoustic fatigue as had previously been concluded. The Directorate's proposed solution to reskin the aircraft in the problem area using the same skin as on the C-5B aircraft, was adopted by the Program Office.

Background

In 1986 San Antonio Air Logistics Center identified the upper forward fuselage skin cracking as a high maintenance problem. One of the cracks was observed to be 48 inches long, causing concern for flight safety. A contractor concluded that acoustic loading from the engine inlets was causing the skin to vibrate, and this was aggravated by large global structural vibration modes. Several structural modifications were recommended and tested, but none of them reduced the stress in the problem area. The contractor then recommended retrofitting the C-5A fleet with acoustically treated engine inlet cowlings to reduce the radiated acoustic energy from the engines. The C-5 Program Office was not convinced that this would solve the problem and was also not convinced that the real cause of the cracking was understood. They asked the Structural Dynamics Branch to undertake an effort to determine the cause of the cracking. The branch used the results from extensive acoustic tests, vibration tests, material and fractographic evaluations, finite element analysis, and two flight tests to determine that the real cause of the cracking was corrosion. These results clearly showed that acoustic energy from the engines was not causing the cracking.

Large Single Crystals of Silicon Carbide Provide More Robust Electronics

Payoff

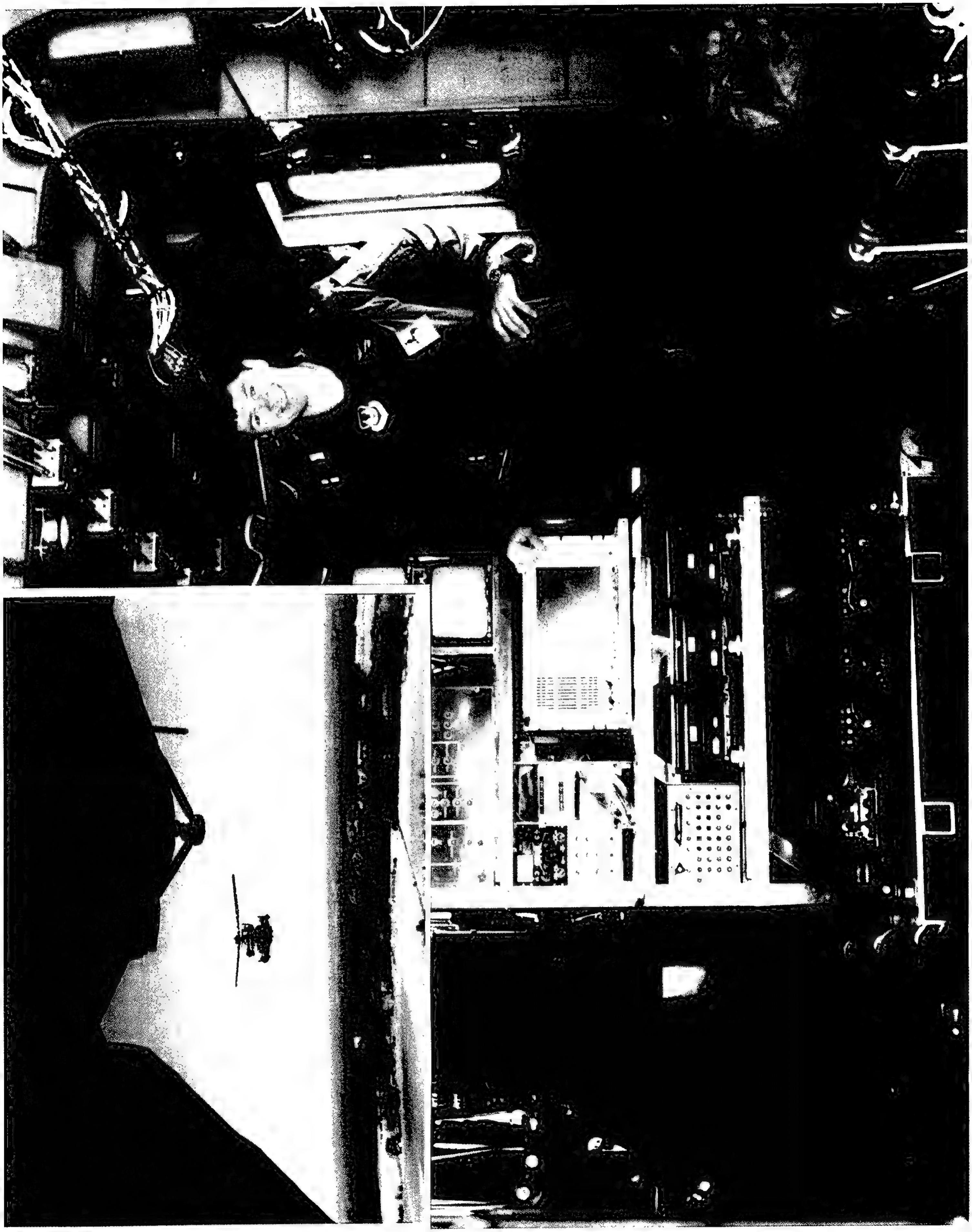
Development of semiconductor devices that use high purity boules of single crystal silicon carbide, like the one shown on the left, will lead to a new family of compact, more powerful and reliable electronic devices for satellites, more effective turbine engine management systems and increased radar sensitivity. Potential dual use applications include commercial aircraft, electric power generation and automobiles.

Accomplishment

Westinghouse Science and Technology Center, Pittsburgh PA, working under contract with the Materials Directorate, has produced high purity boules of single crystal silicon carbide (SiC) with uniform, reproducible properties. SiC is an extremely rugged semiconductor material with excellent thermal properties that is highly resistant to radiation damage and can operate up to 600°C.

Background

Semiconductor materials used in today's electronic components are susceptible to damage from radiation, have limited power handling capability because of their thermal properties and must operate at temperatures below 200°C. Many applications pose severe environmental requirements that cannot be fully satisfied by available semiconductor materials. Examples of these applications include: very high power radar systems; satellites that must operate for long lifetimes in the Van Allen radiation of space; and sensors, which are physically located on or near hot engine parts, that help control aircraft turbine engine operation. The unavailability of large quantities of high purity, single crystal SiC material has been a limitation on the development of new semiconductor devices such as transistors, diodes and controlled rectifiers. Materials Directorate and Westinghouse scientists have demonstrated reproducible growth of single crystal SiC in a low-cost furnace suitable for high volume production. They have produced 2 inch diameter boules of the material, and an effort is continuing to produce larger, 3 inch diameter boules. Development of practical SiC semiconductor devices can now proceed and will lead to a new family of compact, more powerful and reliable electronic devices for both military and civilian uses. This technology supports the Air Force's Integrated High Performance Turbine Engine Technology (IHPTET) and More Electric Airplane (MEA) initiatives.



Intraformation Positioning System (IFPS)

Payoff

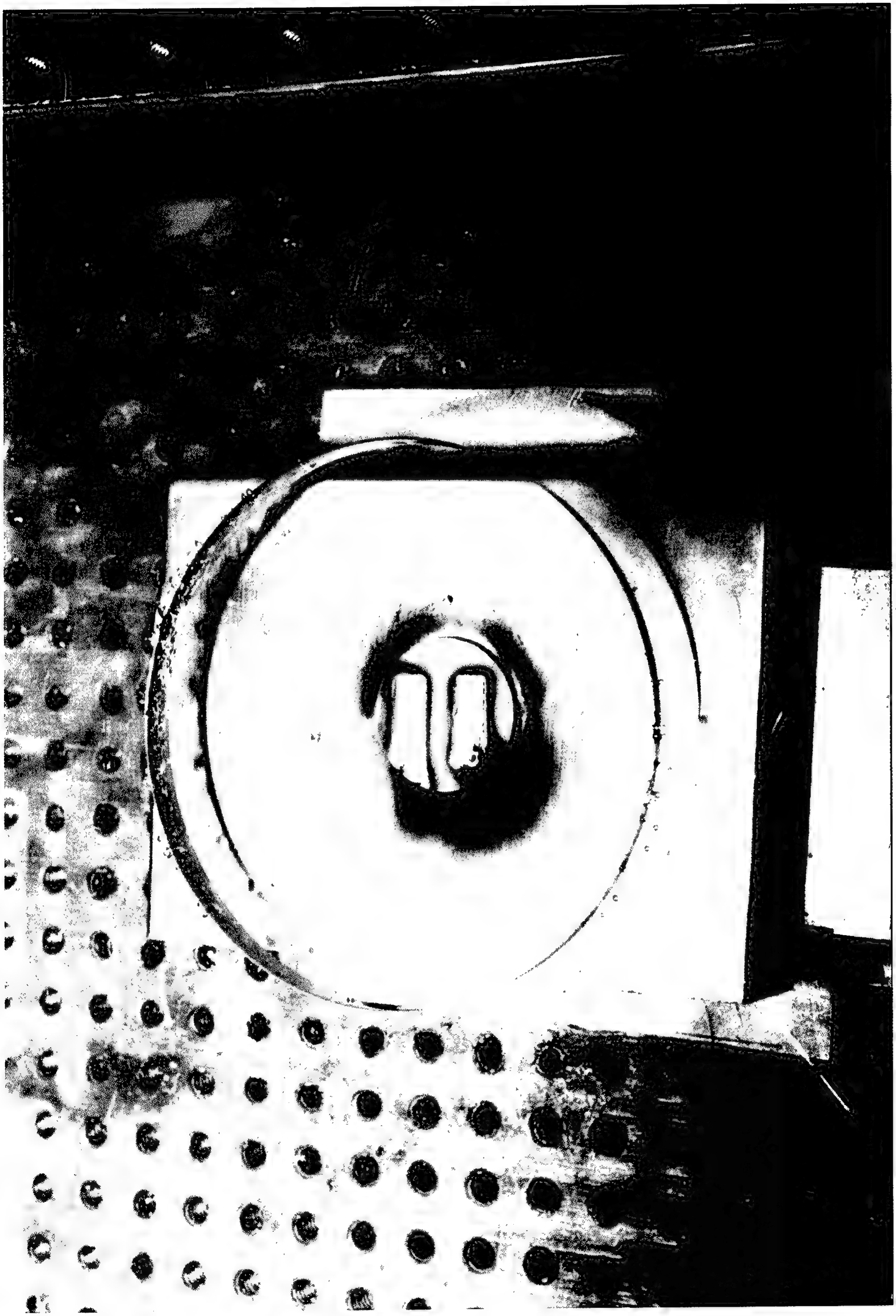
The intraformation positioning system (IFPS) depicted left in a MH-53J helicopter provides a new method to safely rendezvous, join-up and maintain formation flight under severely reduced visibility conditions covertly. IFPS, combined with a highly portable/droppable ground unit, will provide a precision landing capability at austere landing sites. Widespread application in the civilian market would reduce aircraft enroute and terminal spacings at night and in adverse weather and reduce flight costs.

Accomplishment

Through the combined efforts of Wright Laboratory's Flight Dynamics Directorate's Flight Control Division and the Special Mission Operational Test and Evaluation Center, the IFPS was successfully flight demonstrated at Hurlburt Field FL, during March/April of 1993. The IFPS was flown a total of 44 hours on a MH-53J helicopter in operationally relevant scenarios and demonstrated formation placement accuracies of 20-30 feet and the ability to perform precision formation landings using relative global positioning system (GPS) and inertial navigation system (INS) as primary navigation sensors.

Background

The Air Force Special Operations Command (AFSOC) issued a Mission Need Statement (MNS), AFSOC 046-91, Integration of Multiship, Penetration, Low-Level Capabilities, Displays and Commands. The requirement for non-visual, adverse weather, safe formation flight capability contained within the MNS was the primary basis for IFPS. The purpose of the flight demonstration was to evaluate the IFPS algorithms, specifically navigation accuracies of the relative GPS and INS, the ability of the algorithms to detect and provide guidance from potential collision situations, and the ability of the covert IFPS data link to provide sufficient data exchange to permit operations at spacings of 800 feet. This technology also has been listed as a potential technology solution for Air Mobility Command's station keeping (formation positioning) equipment requirement and has been selected by the Joint Special Operations Command to satisfy their precision landing requirement. AFSOC is currently pursuing funding for engineering and manufacturing development of the IFPS for the MH-53J Pave Low helicopter and the HC-130 P/N Combat Shadow Tanker aircraft.



Materials Directorate Validates Laser for Industrial Applications

Payoff

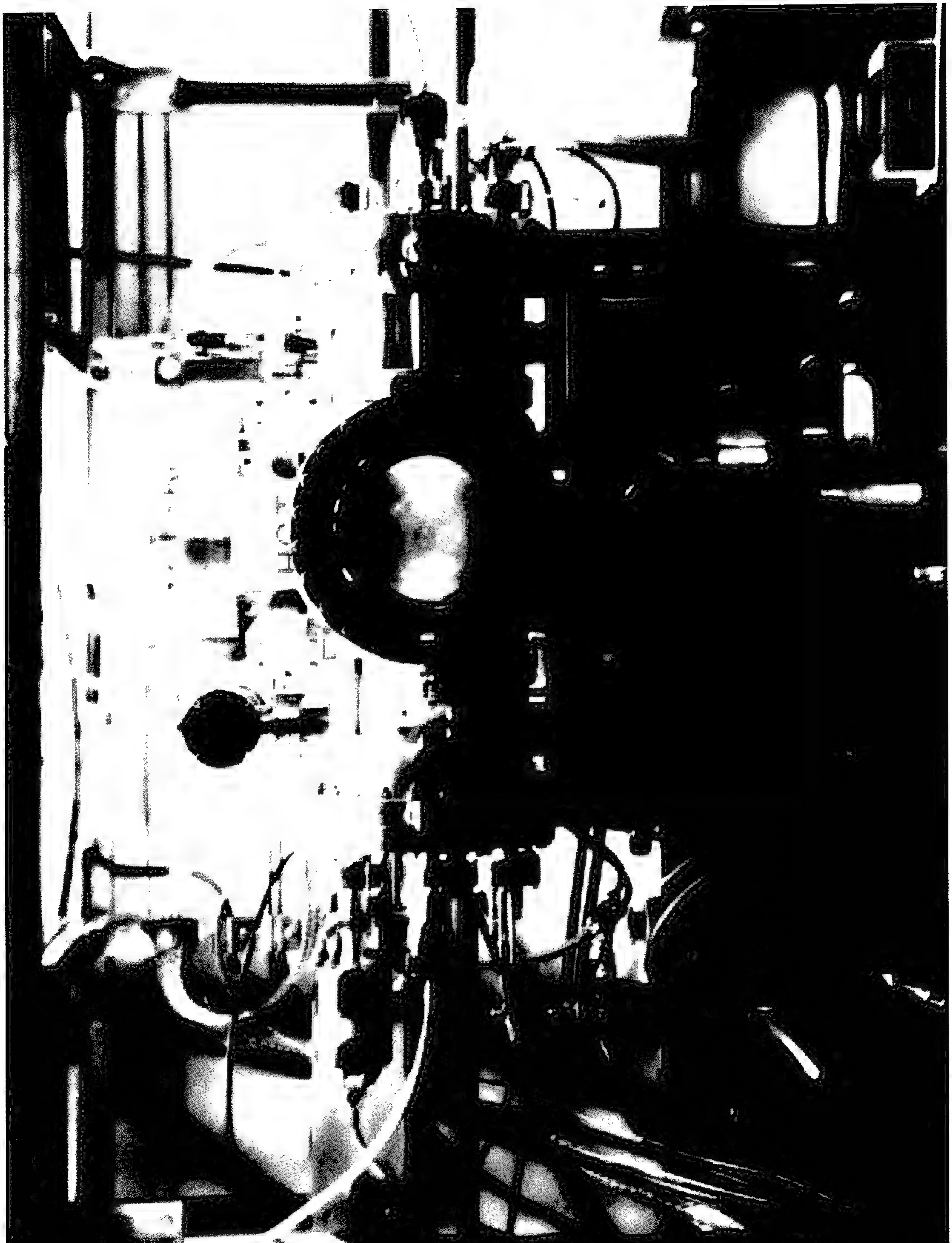
The Materials Directorate's established laser research program enables the transfer of technical knowledge and expertise to industrial organizations to help them produce higher quality items, such as the mixed hafnium carbide, hafnium diboride coating that is reaction sintered on a graphite sample (shown left) using a laser heat source. By transferring the technology to industry, the Air Force is assured that an industrial advanced materials processing capability exists to meet future weapon systems needs.

Accomplishment

The Materials Directorate's Electromagnetic Materials and Survivability Division has assisted a number of industrial organizations in validating the benefits and effectiveness of using lasers for industrial processes. The Division's support has given EG&G Mound Laboratories, General Atomics, General Motors and others the opportunity to accurately assess the use of lasers to make production components without having to first procure lasers and train operators.

Background

Lasers produce large amounts of precisely controlled heat when focused on a target or workpiece and are being used in many industrial processes to melt, cut and weld materials. Many potential industrial users need temporary access to a laser and a trained operator to help them make an informed decision regarding the benefits that can be realized from using a laser in their specific application. The Electromagnetic Materials and Survivability Division has in-house lasers and highly skilled operators that are investigating materials' properties and the interactions of laser radiation with advanced materials. Division scientists have worked with industrial partners to demonstrate that lasers can efficiently produce high quality machined metal parts, components cut from films and reaction sintered coatings on substrate materials. Reaction sintering will provide tough, chemical and abrasion resistant coatings for advanced materials like carbon-carbon composites in hostile environments, such as those present during hypersonic flight and rocket motor nozzles. In most instances, the industrial partners have determined that lasers are efficient, cost-effective tools and have implemented them for use in production processes. Work is continuing with new industrial partners to develop and demonstrate novel methods of using lasers to improve productivity.



New Process Improves Superconductor Materials

Payoff

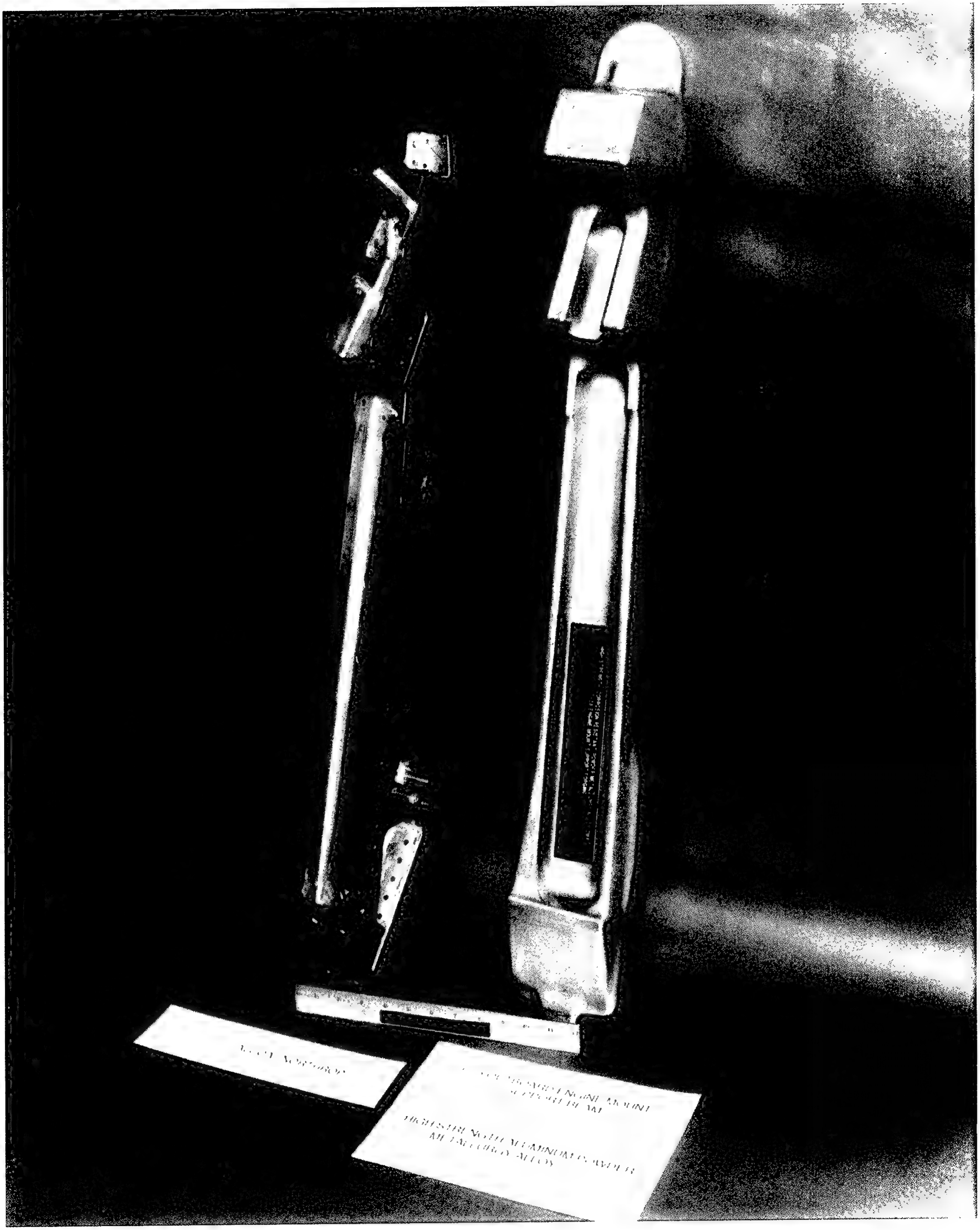
Depicted on the left is a thin-film, thallium high-temperature superconductor deposition chamber showing plasma discharge in the thallium atmosphere. Materials produced in such a chamber by the new, one-step process can be used to produce superconducting devices for high performance electronic applications, including the high speed computer of the future.

Accomplishment

Researchers at Du Pont Central Research and Development, working under a program sponsored by the Materials Directorate, developed a one-step in-situ process for making high temperature, thallium-based superconducting thin films. These films grow epitaxially and have very smooth surfaces which make them very adaptable for fabricating multilayer-thin film devices needed for advanced electronics applications.

Background

Superconducting materials are attractive for various electronic and microwave applications because they have no resistance to direct electrical current and resistance at radio frequencies is very low. A key ingredient to make computers and electronic devices better and faster is superconducting circuit material. New materials have been discovered that exhibit superconducting properties at higher temperatures up to 127°K (-231°F). These materials can remain superconducting at liquid nitrogen temperatures instead of the liquid helium temperatures required by the older superconducting materials. This greatly simplifies the refrigeration system required to keep the materials cold. Some of the new materials of greatest interest use thallium as one of their constituents. Producing these materials by conventional means would require temperatures as high as 850° C, which would result in evaporation of the thallium. A second step, called thallination, would be needed to incorporate the thallium into the material and bring out its superconducting properties. Scientists at Du Pont Central Research and Development, Wilmington DE, working under sponsorship from the Directorate's Electromagnetic Materials and Survivability Division, developed a lower temperature (500-600° C), in-situ process for making these superconducting thin films. Their process involves simultaneous sputtering of barium, calcium, copper and oxygen atoms onto a substrate in the presence of thallium oxide vapor. The process avoids the thallium evaporation problem and does not require the thallination step after processing.



New Aluminum Alloy Exhibits Improved Stress Corrosion Resistance

Payoff

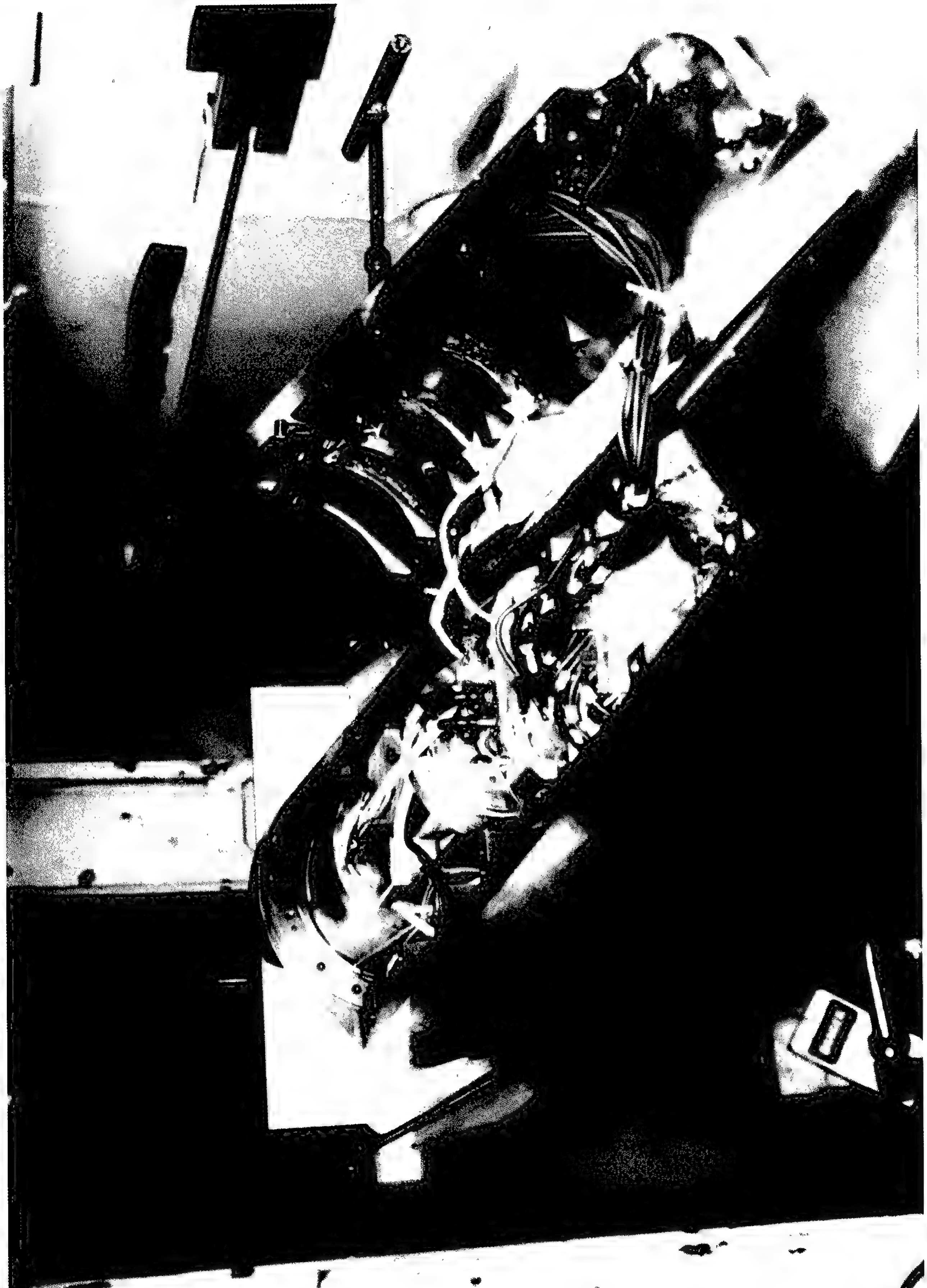
Replacing conventional aluminum components currently used in aging aircraft with components made from an advanced high strength aluminum powder metallurgy alloy, designated X7093, will increase component stress corrosion resistance, thereby, reducing replacement due to corrosion problems. A realistic comparison of the T-38 aircraft's conventional outboard engine mount, made of aluminum 7075-T6 and one made from X7093 are shown on the facing page (far left forged, near left machined), demonstrated the new alloy's improved corrosion resistance while maintaining current fatigue strength.

Accomplishment

Under a program sponsored by the Manufacturing Technology Directorate, the Aluminum Company of America (ALCOA) developed a new aluminum powder metallurgy alloy, designated X7093, which exceeds the stress corrosion resistance of aluminum 7075-T6 currently used in aging aircraft. This new alloy exhibits greater stress corrosion resistance than 7075-T6 with no reduction in yield strength, ultimate tensile strength and fracture toughness.

Background

Air Force aircraft components made of aluminum 7075-T6 have exhibited stress corrosion problems. These components require frequent replacement to avoid possible catastrophic failure. Other alloys exhibit greater corrosion resistance but lack the required structural strength and fracture toughness. To address this problem, the Manufacturing Technology Directorate contracted with ALCOA to develop a high strength, stress corrosion resistant material. To test the improved structural characteristics of this material, Northrop fabricated four powder metallurgy forgings of the left outboard engine mount found in the T-38 aircraft. Following extensive mechanical property testing of these components, the San Antonio Air Logistics Center, Kelly AFB TX, approved a Class II Modification document to allow the engine mount to be installed on a T-38 aircraft for flight test. Three of the engine mounts have been successfully installed and flight tested on T-38 aircraft including two on the T-38 at NASA's Johnson Space Center, Houston TX.



Modular Data Acquisition and Recording System (MDARS)

Payoff

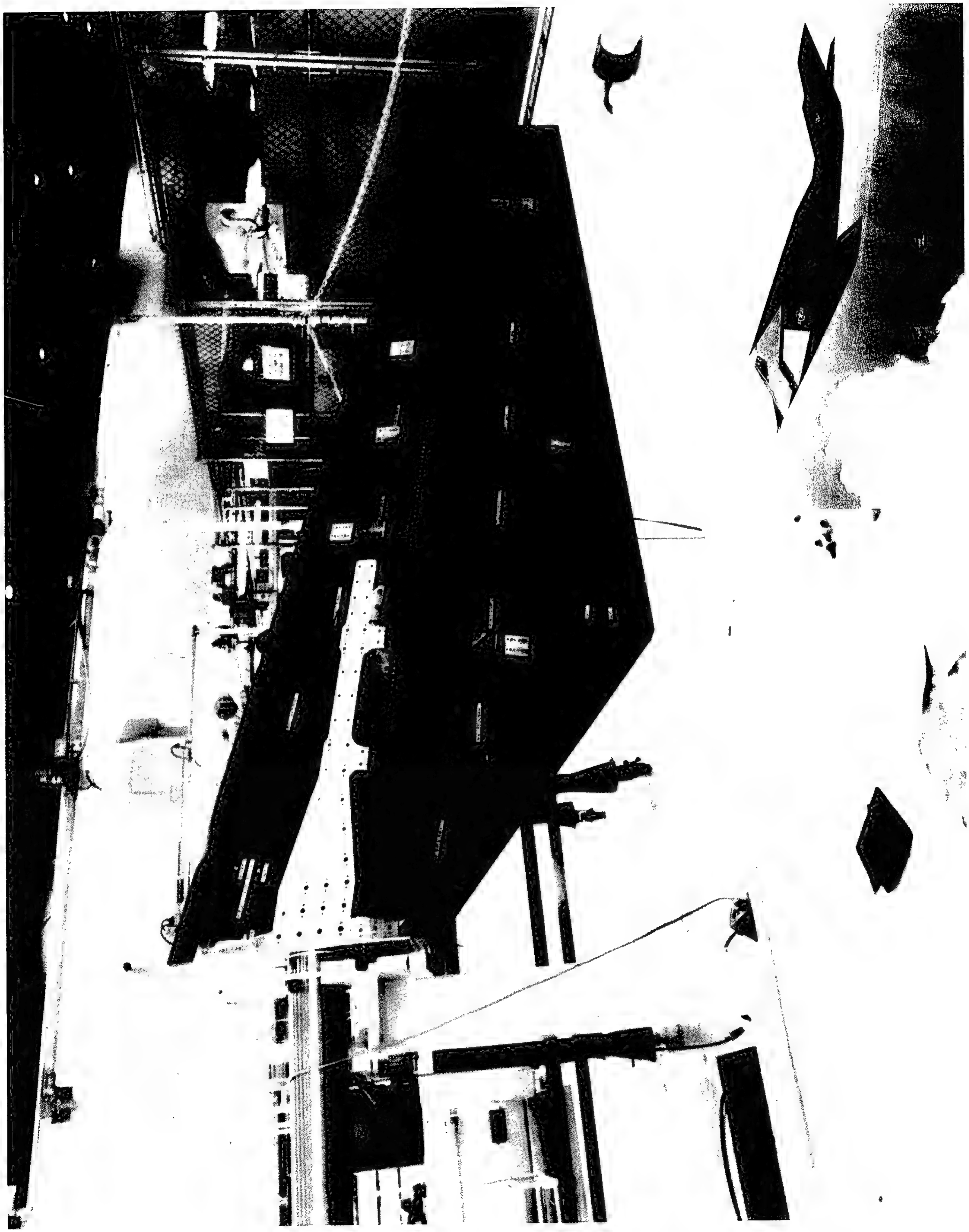
The modular data acquisition and recording system (MDARS) concept employs a multi-sensored wind tunnel model (like the one shown on the left) to provide all forms of aeromechanic data. This model/data system will reduce the cost and time requirements of a developmental wind tunnel test and further expand the data channel capability of most facilities. Its self contained miniature data acquisition system has broad application in fields of both ground and flight testing. The clear advantages of the concept resulted in its adoption by National Aero-Space Plane contractors. It is also being evaluated for use on engine test stands at the Arnold Engineering Development Center.

Accomplishment

The Aeromechanics Division of the Flight Dynamics Directorate has developed a model/data system that allows simultaneous acquisition of all forms of aeromechanic data during a single, dynamic model sweep. It includes a miniature data acquisition system that can be configured to interface with pressure, heat, flux, and force data instrumentation and will monitor up to 1000 data channels.

Background

Wind tunnel testing techniques have changed very little in the past 20 years. Developments in the fields of microelectronics and computer technology on the other hand have been significant. Applying those technologies to the field of wind tunnel testing in innovative ways can have a great impact on the cost and efficiency of wind tunnel testing. The MDARS concept was conceived for this purpose. It couples a multi-sensored wind tunnel model with an 80386 micro computer and employs a test approach which optimizes the system's capabilities. The unique capability of the model/data system is that it allows simultaneous acquisition of all forms of aeromechanic data during a single, dynamic model sweep. In the past, each measurement constituted a separate test. The MDARS concept uses advanced electronics to process the instrumentation signals inside the model and transmit them over a single wire or fiber optic cable as a multiplexed data stream. The micro computer controls the on-board data acquisition system, records the transmitted data and immediately places the wind tunnel data in the hands of the project engineer at completion of the test.



Thermoplastic Composite Material Improves Stealth Fighter Performance

Payoff

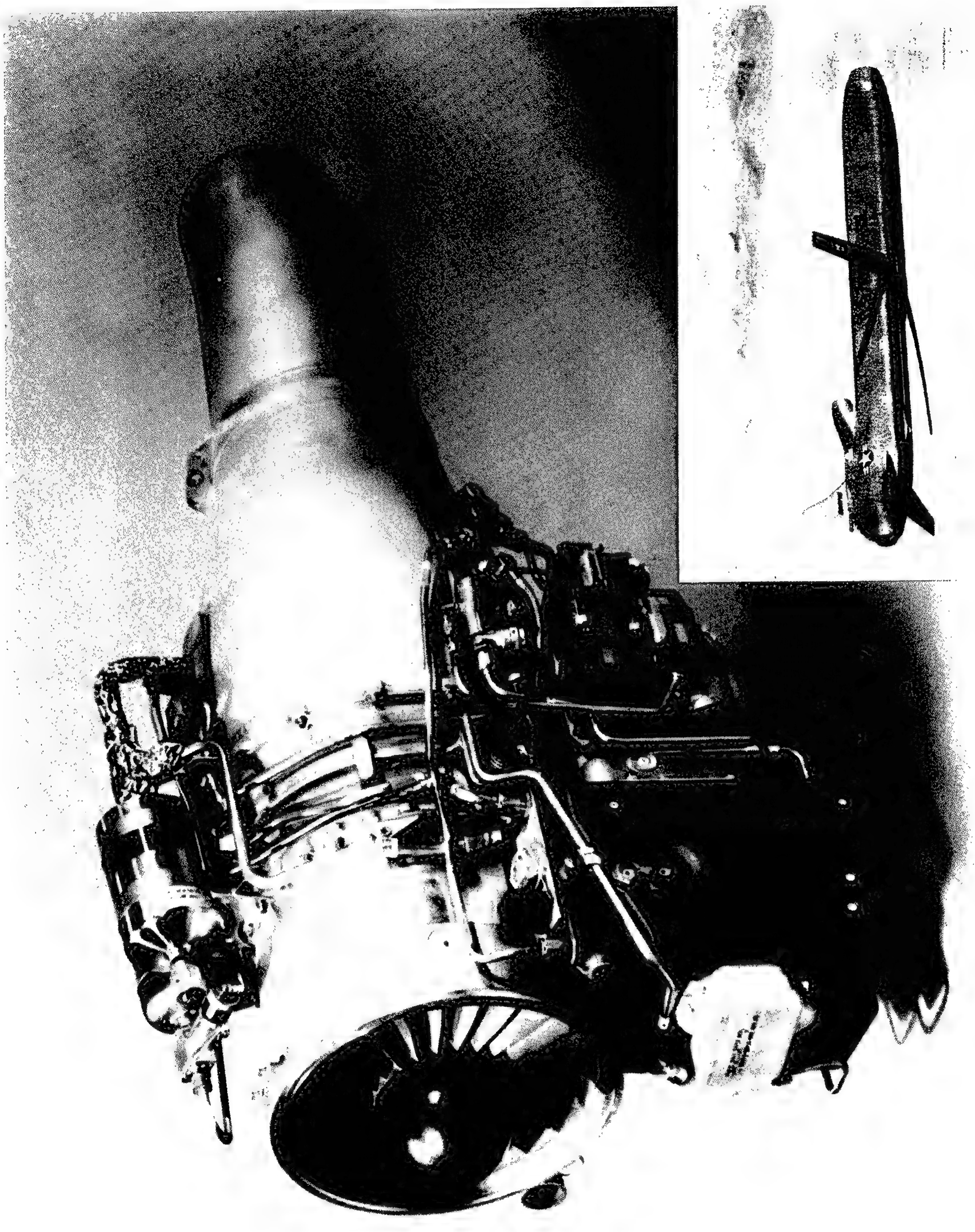
Transitioning thermoplastic materials and processes for use on the F-117A solved the Stealth fighter's rudder flutter problem, while producing an 18 percent weight savings over a metal structure solution. Its use in the aircraft's rudder assembly shown on the left (top skin removed) represents a milestone for nonmetallic structural composites by demonstrating confidence in the technology for use in primary flight-critical aircraft structures.

Accomplishment

Research performed at Lockheed Advanced Development Corporation (LADC), under contract with the Materials Directorate, has led to the first use of a thermoplastic composite for rudder assemblies on an operational Air Force aircraft. Its use on the F-117A solved a significant flutter (vibration) problem being encountered with the fighter's initially designed aluminum rudder assemblies.

Background

Flight control assemblies of today's aircraft need to be as stable as possible to withstand the magnitude of stresses and strains placed on them during flight. The Air Force's F-117A Stealth fighter was experiencing significant flutter problems with its initially designed aluminum rudder assemblies. Engineers tasked to solve the problem considered two options to make the fighter's rudder assemblies stiffer—larger, aluminum rudder assemblies or assemblies made from advanced thermoplastic composites. They chose the thermoplastic design because it provided the required stiffness and is 18 percent lighter than the aluminum design. The box structure of the rudder assembly, including the skins and substructure, is made totally of thermoplastics, a material made possible by research performed at LADC and the Materials Directorate. The major part of the thermoplastic box structure is made from AS-4/APC-2 (graphite fiber/thermoplastic resin) unidirectional prepreg tape. The skins are hot-head tape laid—an entirely new process that originated under a Materials Directorate contract with Lockheed Corp. The process has been implemented in the production of the F-117, the first production implementation ever for such a technology. With the exception of the structure's ribs, all of its parts are consolidated in an autoclave. The ribs are injection molded from chopped graphite/PEEK, a very low cost, high volume process. Extensive testing proved that the composite was mechanically superior to metal for flutter, strength, fatigue and damage tolerance.



Improved Grease to Save Millions for Cruise Missile Maintenance

Payoff

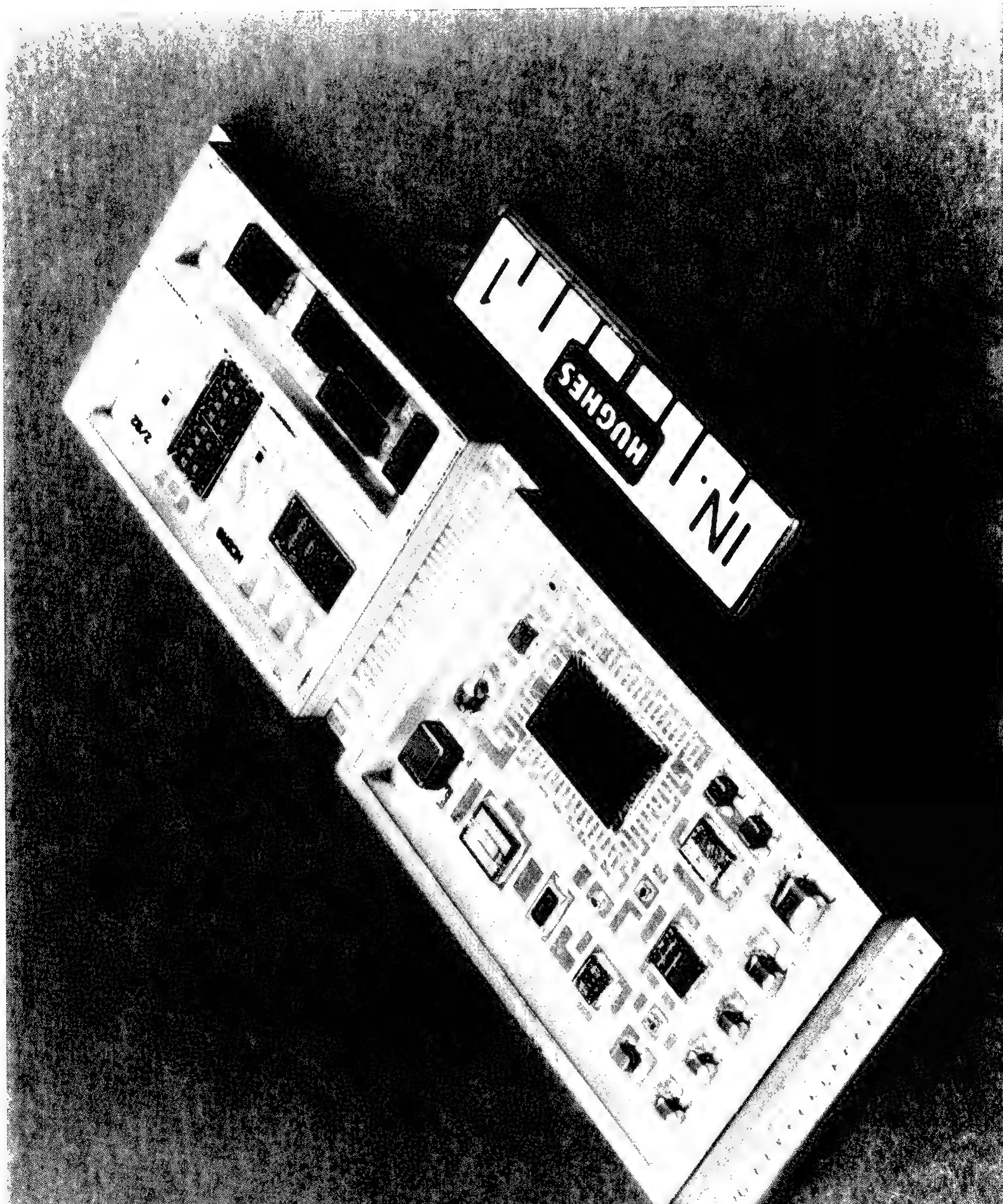
Use of the new synthetic grease on the Williams International F107 cruise missile gas turbine engine (shown left) has increased the engine overhaul interval by more than 250 percent. Logistics engineers have estimated the new lubricant will save more than $70 million during the operational lifetime of cruise missiles. The multipurpose nature of the grease makes it well suited for other military, industrial and civilian applications such as; automotive lubricants, recreation equipment and agricultural machinery.

Accomplishment

Scientists from the Materials Directorate's Nonmetallic Materials Division developed a new synthetic grease for use in cruise missile engine bearings that has extended the missile shelf life to more than 60 months. Accelerated tests have shown that a sixfold shelf life increase may be possible using the new grease.

Background

The mineral oil based grease originally used to lubricate the air launched cruise missile (ALCM) and Tomahawk sea launched cruise missile (SLCM) engine bearings had a deployed shelf life of 24 months. This shelf life limitation required each missile to be periodically removed from service for an engine overhaul to remove the bearings and replace them with freshly lubricated bearings. Scientists from theMaterial Directorate's Non-metallic Materials Division developed and transitioned a new synthetic hydrocarbon polyalphaolefin grease that has extended the missile engine shelf life to more than 60 months and real-time tests are continuing. This new grease has multipurpose capability and exhibits excellent high temperature stability and corrosion prevention properties, as well as the ability to operate under high loads. It also has high resistance to water washout. Directorate scientists worked with engineers from the Joint Cruise Missile Project Office (JCMPO) and the engine supplier, Williams Intl. of Walled Lake MI, to transition the grease into operational use. A military specification that fully describes the mineral oil based grease and the tests to ensure its quality will be prepared.


HUGHES

Manufacturing Technology for Transmit/Receive Modules

Payoff

The transmit/receive (T/R) module will no longer be the major cost driver for an active phased array system. When configured for high volume manufacturing, it is projected that the module cost will be reduced from $8,200 to less than $400 with a predicted reliability of greater than 125,000 hours mean time between failure (MTBF) for active phased array systems.

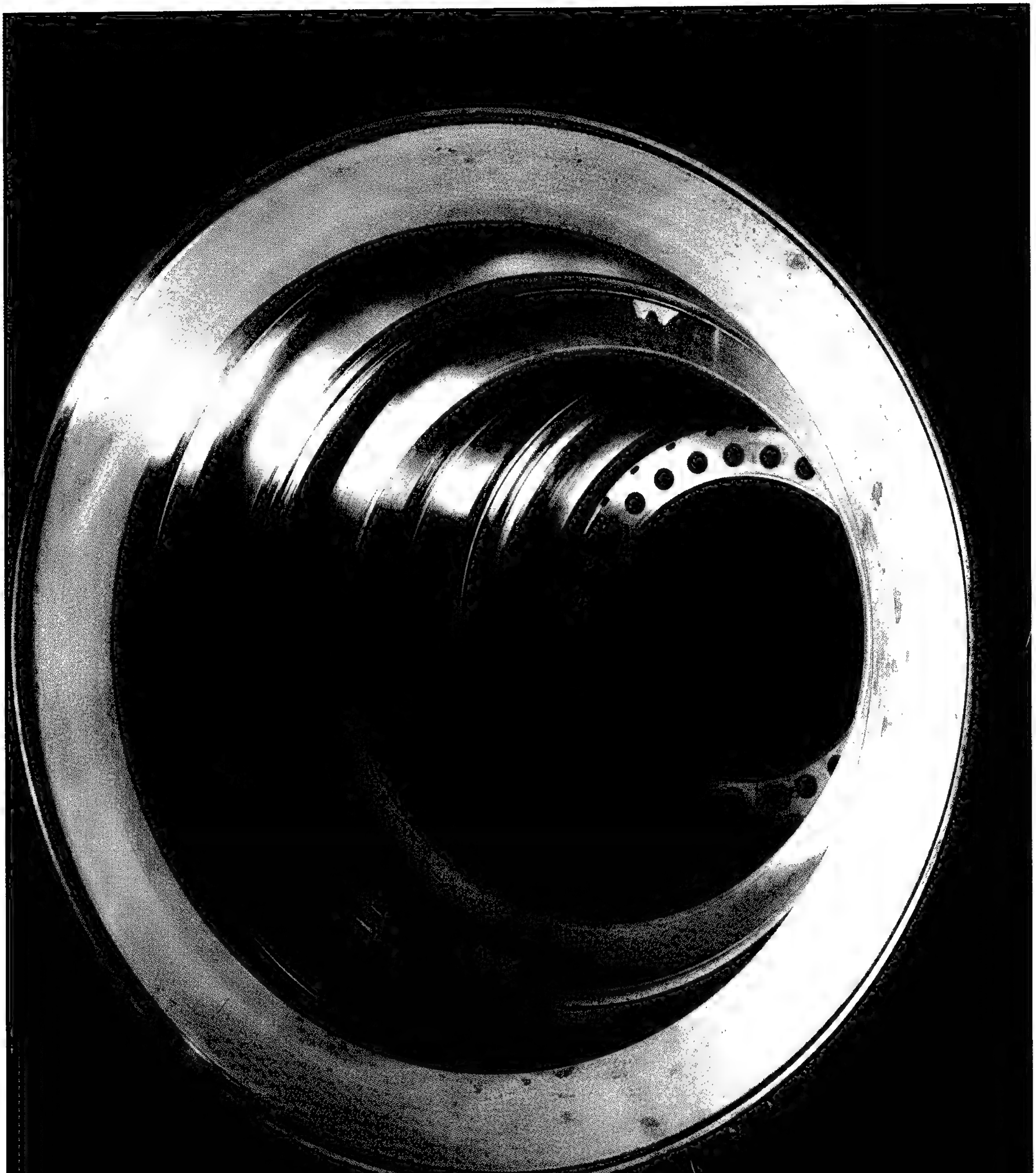
Besides application of T/R modules in ground-based, airborne and active element phased array radar systems, such as the F-22's, spin-off products include the GM Hughes near obstacle detection system called Forewarn ™, produced by HE Microwave. These are production detector systems which attach to the bumpers of cars and buses for accident avoidance.

Accomplishment

The program with Hughes Aircraft, sponsored by Wright Laboratory's Manufacturing Technology Directorate, has reduced T/R module assembly time by a factor of 200, reduced the number of interconnects by almost 90%, decreased test time from 17 hours to less than 10 minutes and significantly increased reliability.

Background

Active element phased array systems utilizing T/R modules are one of the most promising technologies for future ground-based, airborne and space based radar applications. Advanced aircraft require active array radar for detecting and tracking multiple targets, and for the benefits of improved reliability, lower maintenance cost and reductions in size and weight. The Solid State Electronics Directorate and Materials Directorate set the stage for solid state radars by demonstrating the feasibility of active electronically scanned arrays (AESA) through programs dealing with the design and manufacture of gallium arsenide semiconductors, the development and characterization of advanced microwave packaging materials and several iterations of T/R module designs. The integration of this technology into a complete array with suitable systems characteristics was carried out by the Avionics Directorate. The Flight Dynamics Directorate provided significant technical expertise in thermal design and control while the Signature Technology Office provided critical inputs into designs for low observability. To date, the cost of the T/R modules has been the major drawback to active phased array systems. An average phased array system for an aircraft would require 2000 modules. At $8,200 per module, the cost of modules for one radar would be in excess of $16 million. Because of the high T/R module cost and the quantities required for this approach, Air Force program offices developing new aircraft have been reluctant to commit to an active element phased array design. The feasibility and validation T/R microwave modules for previous Wright Laboratory development programs and many new systems have only been built in small prototype quantities or very limited production quantities, but their use had been largely limited to ground-based systems that were not as cost sensitive. Costs are extraordinarily high as a result of complex design, the need for precision fabrication, the cost of parts and materials, and the general lack of adequate assembly, test and automation equipment. The Manufacturing Technology Directorate initiated the development of new manufacturing technology for radar T/R modules to reduce T/R module costs and demonstrate that the technology is producible for future weapon systems.



Metal Matrix Composite (MMC) Compressor Rotor - R&D 100 Award

Payoff

Identified by R&D Magazine as one of the 100 most technologically significant products of 1993, the advanced titanium metal matrix composite (MMC) compressor rotor shown on the left is an application of a new material that enables the implementation of advanced aerodynamics in a major engine component. When used in an entire compressor, MMC technology offers a 70 percent weight savings.

Accomplishment

The titanium MMC compressor rotor was recognized by R&D Magazine as one of the 100 most technologically significant products of 1993. The award was given to a team of General Motors (Allison Gas Turbine), Textron Specialty Materials and Aero Propulsion and Power Directorate personnel for their work on the development of the Allison Advanced Turbine Engine Gas Generator core XTC-16 rotor. This rotor has a pressure ratio 40 percent greater than current production compressors in half the number of stages.

Background

The application of advanced materials in innovative structural concepts to implement advanced aerodynamics is required in all major engine components if the goal of the Integrated High Performance Turbine Engine Technology (IHPTET) program is to be achieved. New aerodynamic concepts for compressors using "high throughflow" technology and swept blading reduce the number of compressor stages and increase efficiency. However, these concepts require considerably higher rotation speed, which leads to heavier rotors. Use of high specific strength MMCs in reinforced rings to replace compressor disks enable the design of rotors that have half the weight of conventional compressor rotors. The XTC-16 rotor would weigh at least as much as a current compressor rotor if fabricated from the conventional nickel-base superalloys. The use of a "bling" (bladed-ring) design, instead of a disk, is made possible by the very high specific strength of MMCs (2-3 times that of nickel superalloys). It is this specific strength increase that allows the free-ring radius to be increased, thus eliminating the conventional webs and bores. The titanium MMC rotor was tested in an advanced turbine engine as a demonstrator under the sponsorship of the Aero Propulsion and Power Directorate.

New Composite Material Improves F-117A Fuselage Trailing Edge

Payoff

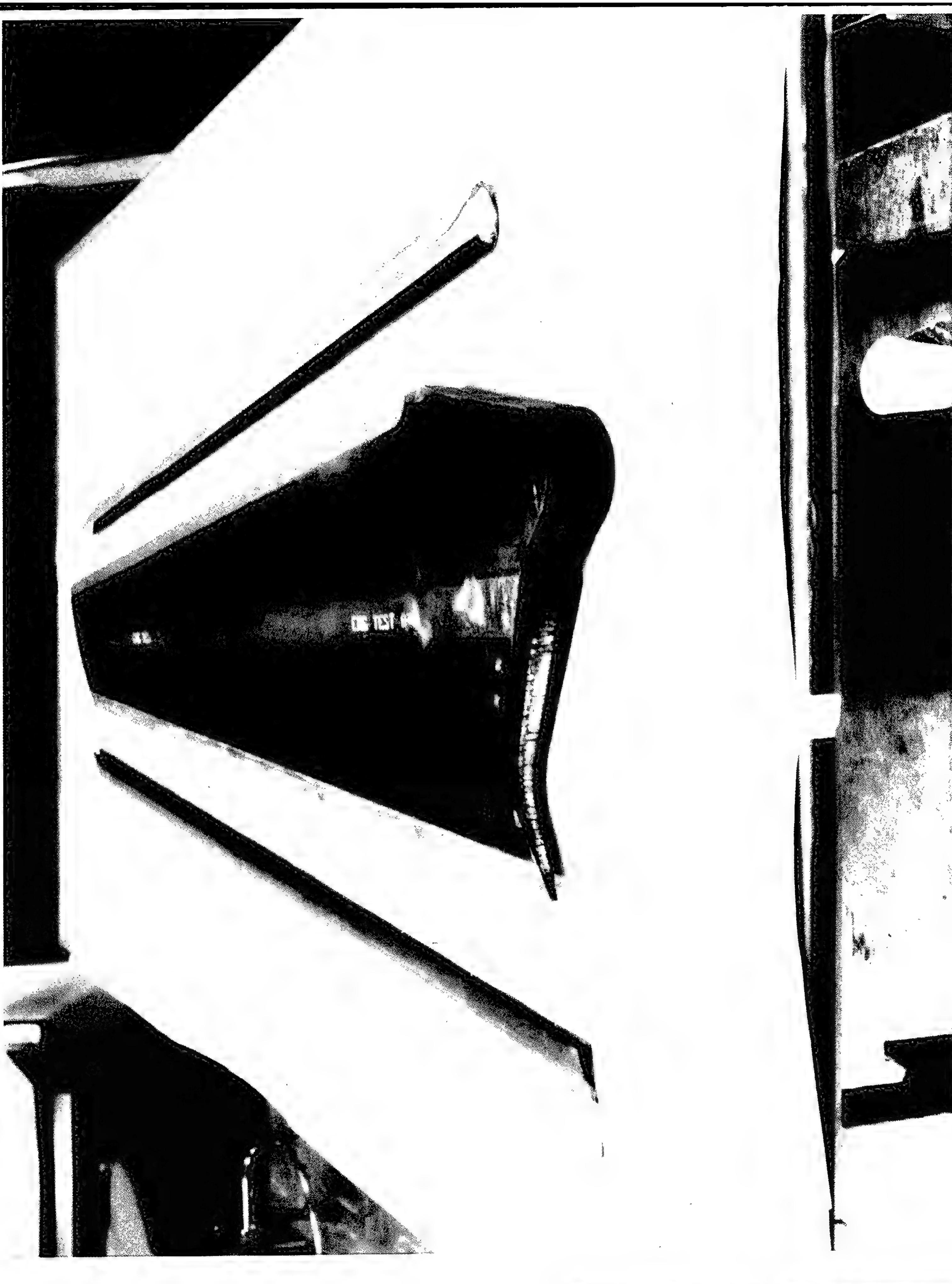
AFR700B resin offers aircraft designers an advanced light-weight composite material for high temperature applications. Using the resin for in-house fabrication of parts to solve a recurring heat damage problem on the fuselage trailing edges of the F-117A stealth fighter will save the Air Force at least $5 million.

Accomplishment

A new high temperature composite material resin, developed by Wright Laboratory's Materials Directorate, is being used to solve a recurring heat damage problem on the fuselage trailing edges of the F-117A stealth fighter. Their AFR700B resin has increased the temperature capability of organic matrix composite by 150° F and will improve the aircraft's performance, while maintaining its low-observable profile.

Background

Air Force performance requirements continually demand more of aerospace materials. They must be lighter and stronger while operating at increasing temperatures. To help meet these demands, researchers at Wright Laboratory's Materials Directorate have developed an improved resin, called AFR700B, that increases the maximum operating temperature for composite materials. The F-117A aircraft has fuselage trailing edges made from composite materials that were being damaged by exposure to high temperatures. Hot exhaust gases from the aircraft's engines were charring the trailing edges making replacement of the composite material necessary. Scientists and engineers from the Directorate's Nonmetallic Materials Division worked jointly with the F-117 System Program Office (SPO) at Sacramento Air Logistics Center (SM-ALC) and the USAF Advanced Composite Program Office to use the AFR700B material and correct the problem. The Materials Directorate supplied the AFR700B prepeg materials to SM-ALC who fabricated the trailing edge parts. The parts were furnished to the Consolidated Test Facility for a flight test. The flight test proved that the AFR700B parts performed satisfactorily and the SPO and SM-ALC accepted them for use on all F-117 aircraft. SM-ALC determined they could fabricate the parts in-house at a cost $5 million below the price estimated by an outside vendor. SM-ALC is collecting data to determine life cycle cost savings by using the AFR700B trailing edge parts.



Improved Process Reduces Cost of Missile Wings

Payoff

Using advanced integrated development techniques, the number of manufacturing steps for missile wing box assemblies (like the one shown on the left) has been reduced from 55 to 16. Along with the overall 26 percent cost savings, the improved process has reduced associated support costs by 60 percent, material costs by 39 percent, tooling costs by 73 percent and autoclave usage by 58 percent.

Accomplishment

Hughes Missile Systems of San Diego CA, under contract with the Manufacturing Technology Directorate, has improved the process and reduced the cost of producing wing box assemblies for missile systems. By using advanced integrated product development techniques, the number of steps it takes to manufacture the assemblies has been reduced from 55 to 16, resulting in an overall 26 percent cost savings.

Background

Wing box assemblies for advanced missile systems with low observable features have a large number of detailed parts requiring labor intensive work. This results in high fabrication and assembly costs along with high rejection rates. To lower the cost of manufacturing advanced missile wing assemblies, Hughes looked at the three sections of wing design; the wing box, the trailing edge and the leading edge. Their engineers researched ways to establish low-cost manufacturing techniques for composite aeroelastic tailored cruise missile wings without sacrificing system requirements. To achieve their overall objective, the new wing design had to be easier to produce and at a significant cost savings over original wing box assembly methods. A team consisting of members from key technology and manufacturing areas was assembled to apply integrated product development techniques. The team planned, coordinated and supported the program through all phases to ensure knowledge was not lost from one phase to another, and that lessons learned were used to assist production planning and manufacturing procedures. Taguchi techniques (methods of developing a test plan) were employed in formulating and evaluating alternative manufacturing designs, and these techniques supported the engineers ability to meet all performance requirements and achieve expected cost savings. In the final design, the wing box and training edge were integrated into one with the leading edge cast on the wing box.

6-4-13

New Coatings Improve Infrared Window Durability

Payoff

Applying new protective coatings, developed under a program sponsored by the Materials Directorate, to infrared (IR) sensor windows, like the zinc sulfide dome shown on the left, will reduce maintenance and life cycle costs by reducing the frequency of window replacement and eliminating the need for dome covers on the Maverick missile. Savings of $5 million in maintenance and life cycle costs are anticipated.

Accomplishment

New protective coatings developed under a program sponsored by the Materials Directorate's Electromagnetic Materials and Survivability Division will increase the service life of "windows" used to protect IR sensors on Air Force aircraft and weapon systems for navigation, threat detection and targeting. These coatings, developed by the Raytheon Company of Lexington MA, have shown an increase in rain damage threshold velocity

Background

IR sensors are used on many Air Force airborne systems for navigation, detection and targeting. These sensors perform their functions through "windows" that protect them from direct exposure to harsh flight environments and are transparent to IR radiation. The windows, which are damaged by exposure to air flow, dust, rain and other airborne debris during flight, must be periodically removed and replaced to maintain system performance. To increase the service life of the windows, Raytheon Company developed coatings that are formed by depositing multiple thin layers of zinc sulfide and yttrium oxide directly onto the zinc sulfide window material. The Reliability and Maintainability Technology Insertion Program (RAMTIP) Office has selected this technology for transition and is funding the scale-up and transition efforts. Arrangements are being made to transition the new protective coatings for use on IR sensor systems in Maverick missiles, Low Altitude Navigation and Targeting Infrared for Night (LANTIRN) navigation and targeting systems, and the F-22 aircraft.


3
4
5
Defense Syst

Advanced Metal Matrix Microwave Packages for Multi-Chip Assemblies

Payoff

Using advances in aluminum silicon carbide (AlSiC) metal matrix technology, microwave packages like the one shown on the left have been demonstrated for airborne phased array radar, electronic warfare, smart munitions and communication applications. This new technology will offer system designers a low cost alternative for meeting weight requirements of present and future microwave systems. Reduced life cycle costs is an expected benefit of this light weight AlSiC metal matrix technology.

Accomplishment

Under a program sponsored by the Solid State Electronics Directorate, Texas Instruments demonstrated the feasibility of fabricating light weight ceramic metal housings for active aperture transmit/receive (T/R) modules. The process developed resulted in the first thin walled, hermetic AlSiC package. As a result of this effort, Texas Instruments and the Directorate were jointly awarded a 1992 R&D 100 Award by R&D Magazine for the development of Light Weight Ceramic-Metal Matrix Composite Microwave Packages.

Background

Active array radars for airborne and space-based applications require large numbers of T/R modules in each aperture. The cost of these modules has been, and is continuing to be, a concern for transitioning solid state array technology into Air Force systems. Housing weight is another concern, as a significant portion of the active array weight is due to the metal housings. The AlSiC metal matrix technology is cost competitive and offers significant weight savings over metal/metal systems, such as Kovar (combination of iron, nickel and cobalt), iron/nickel and copper/molybdenum that are used for present T/R modules. Furthermore, light weight is a primary requirement for large space-based solid state array systems, making the AlSiC material an enabling technology. Any new material considered for this application must have an acceptable coefficient of thermal expansion match with GaAs and thermal conductivity equal to or better than aluminum.

Mobile Automated Scanner (MAUS III) Saves Time

Payoff

The mobile automated scanning system, demonstrated on the A-10 aircraft composite leading edge shown on the left, will allow weapon system manufactures and maintenance personnel to perform materials and structures inspections of large and curved composite and metal surfaces in a fraction of the time required by current devices. The technology has been validated in demonstrations at Sacramento, Oklahoma City and Ogden Air Logistics Centers, as well as Northrop Corporation and Douglas Aircraft Company.

Accomplishment

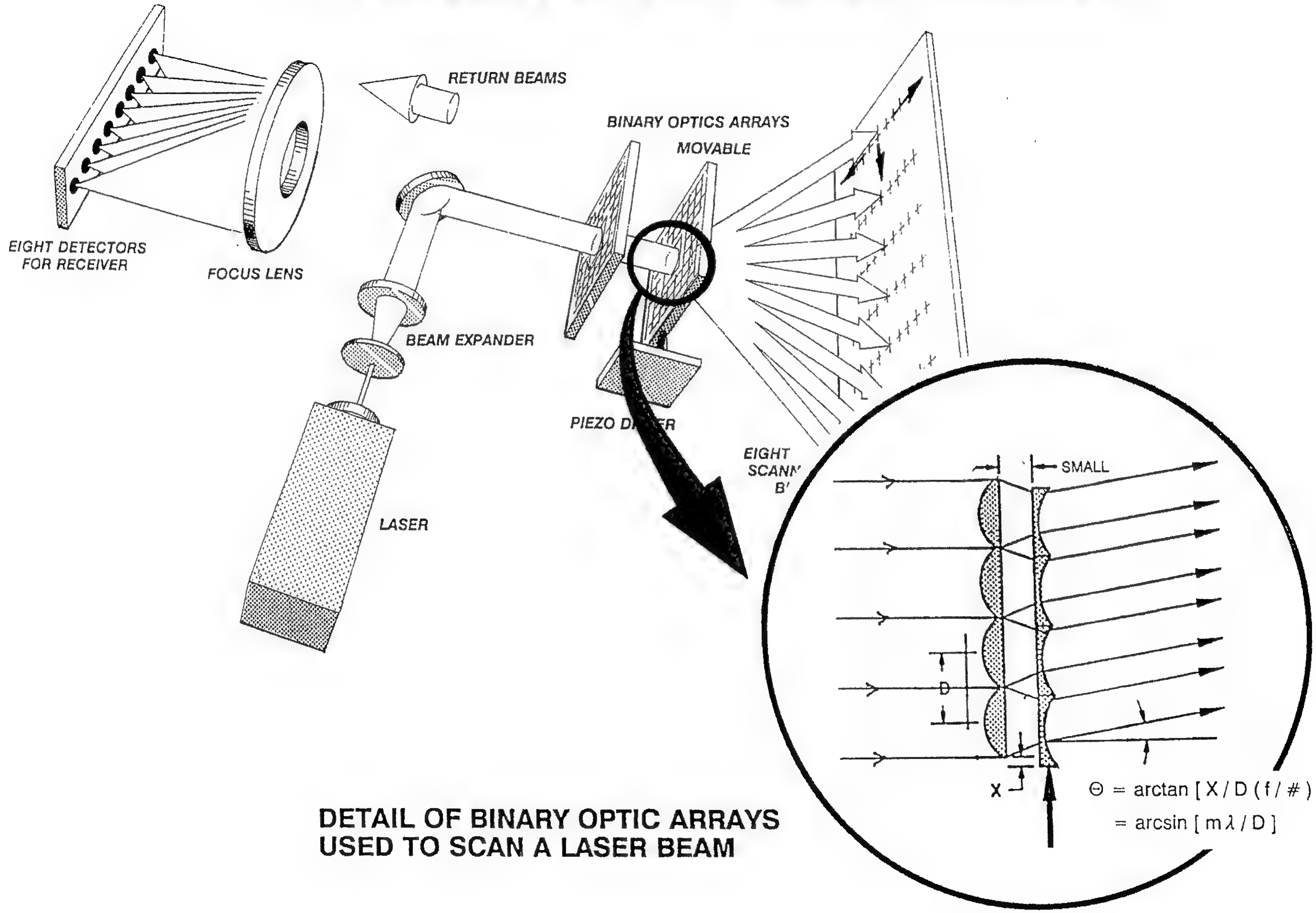
A joint advanced development effort between engineers at the Materials Directorate and McDonnell Douglas Corporation has resulted in the development of a portable, automated scanner capable of inspecting large areas of different aircraft structural materials and configurations in a fraction of the time required by current systems. The scanner is hand-held, comes in three different sizes depending on the application, and has a set-up time of only 10 minutes, compared to 45 minutes or more for a current, fixed scanning system. A six fold decrease in scanning time was recorded for a specific application at Sacramento Air Logistics Center.

Background

The integrity of materials used to produce Air Force weapon systems determine, to a large extent, the day-to-day ability of those systems to perform their mission. Determining the integrity of materials, especially on large areas of operational systems, has challenged maintenance personnel for years. Damage, such as delamination, cracks, corrosion, bondline flaws, porosity and foreign inclusions may result from improper fabrication and assembly practices or from in-service damage. Much of this damage can occur within the material and may not be visible. Nondestructive evaluation systems have been used for years to find possible defects in materials. However, today's typical inspection devices can only cover small areas in a reasonable amount of time and are difficult to use on curved or highly contoured surfaces. McDonnell Douglas Corporation, under a program sponsored by the Materials Directorate, has developed the mobile automated scanner (MAUS III) system to simplify inspection of large area composites and metals. This system uses ultrasound or eddy current to detect damage in material applications, such as composite laminates, co-cured complex composites, bonded assemblies and metallic structures. It employs ultrasonic transducers or eddy current probes and guide wheels to keep constant contact with the surface being inspected. Software developed for this system allows for flying dot, A-scan and high resolution C-scan displays. Extensive data interpretation tools, a programmable system setup and archival data storage are also included in the software.

LASER SCANNER FOR LADAR APPLICATIONS

2-D BINARY OPTICS LASER SCANNER



DETAIL OF BINARY OPTIC ARRAYS USED TO SCAN A LASER BEAM

Binary Optics Laser Scanner

Payoff

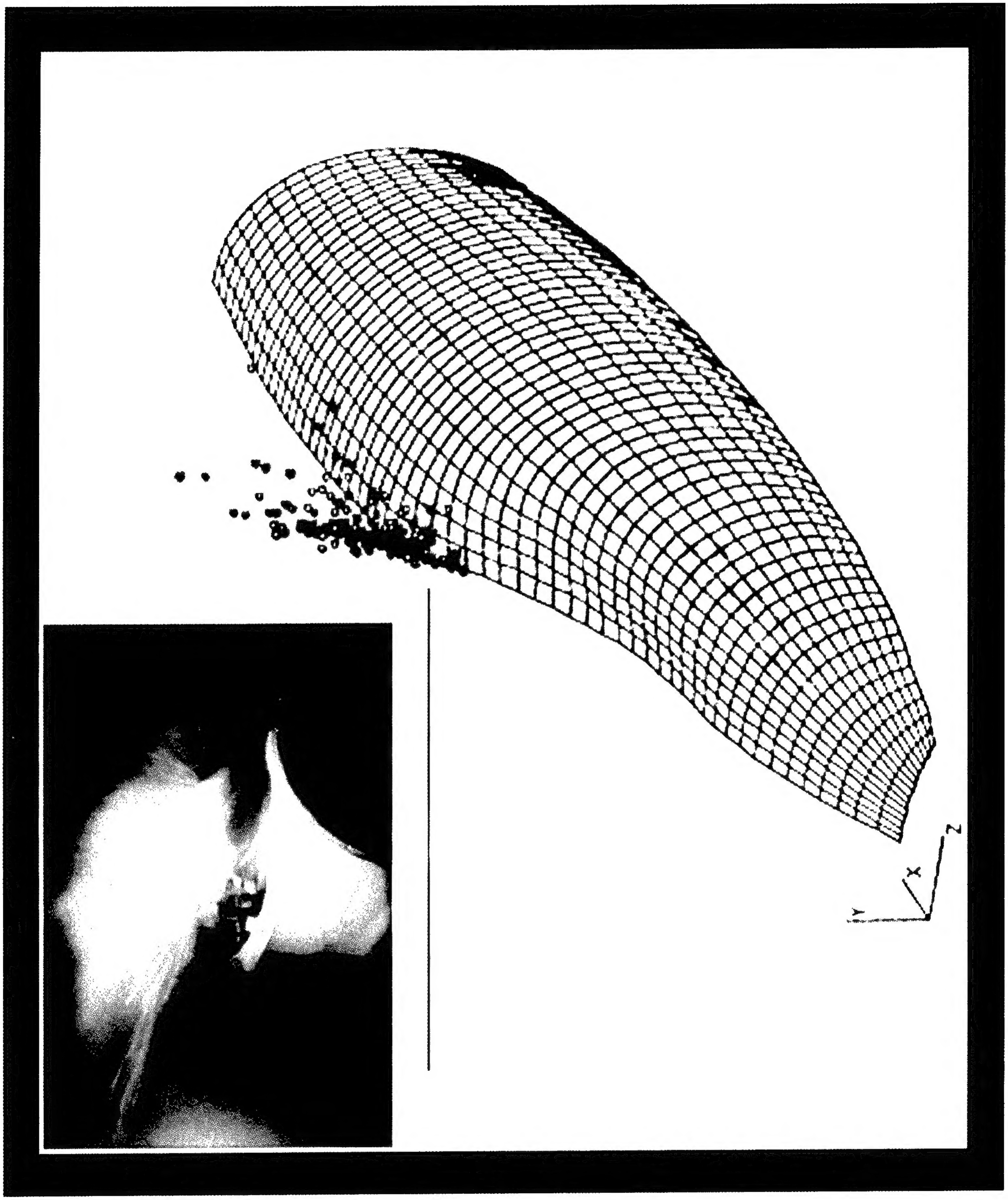
The binary optics scanning technology provides a high performance scanner that is precise, compact and durable. It covers the laser radar (LADAR) area of interest at least five times faster than present systems. The new scanner eliminates mechanical gimbals and simplifies the optics for LADAR systems, making the unit cost 25 percent less than present systems in use. This technology has commercial application in areas such as robotics, parts identification and inspection, or any industry needing high-speed optical scanners.

Accomplishment

The Armament Directorate has made a significant technology breakthrough in LADAR. A binary optics laser scanner, developed by ADA Optics, Inc. MN, under a Phase II Small Business Innovative Research program sponsored by the Directorate, will allow LADAR seekers to scan the ground quicker and thus locate their targets sooner than current systems. Instead of searching an area with a single laser beam, as is used by present LADAR systems, this scanner splits the beam into several subbeams that simultaneously scan an area.

Background

A LADAR consists of a laser, detector and timing circuit. The laser transmits a beam of radiation to a small spot on an object. The radiation is reflected back to the LADAR detector and the elapsed time is computed and converted to range. By moving the beam from point to point on an object, the range to each point on the object can be measured very precisely. In current LADAR systems, the beam is moved from point to point by moving a mirror to scan a line across a scene. The object and its surrounding background is then scanned one line at a time. This provides a precise, three-dimensional picture of the scene containing the object. By adding an image processing computer, the object can be identified in the scene by its geometric shape. With the new system, using more beams and more detectors, the scene can be scanned much faster. The binary optic laser scanner uses low-cost binary optical lens arrays that split a single high-power laser beam into multiple lower power sub-beams which scan over the object/background scene of interest. The binary optical elements can be fabricated using the same etching techniques used for mass production of integrated circuits. They also can be designed to transmit radiation at only the laser wavelength so that they filter out stray radiation, thus eliminating the need for separate optical filtering elements.


Z
X
Y

New F-16 Prototype Canopy System

Payoff

Using finite element analysis in the early stages of development of the aircraft transparency system eliminates the costly, time consuming and risky engineering methods of the past. This capability resulted in a new prototype F-16 canopy system that demonstrated 4 pound bird impact resistance at 540 knots and is ready for service life performance evaluation in the operational environment. This canopy system is being transitioned to service testing through a cooperative effort with Ogden Air Logistics Center.

Accomplishment

The Flight Dynamics Directorate's Aircrew Protection Branch successfully developed an F-16 prototype canopy capable of withstanding a 540 knot/4 pound birdstrike (currently 350 knots). Using a newly developed finite element analysis program which is a full order of magnitude faster than previous codes, the F-16 prototype canopy was designed in just two weeks using ten design iterations. The first canopy fabricated based on this design successfully demonstrated 4 pound bird impact resistance at 540 knots.

Background

Nearly ten years ago, numerous months of "cut and try" engineering produced the current F-16 canopy which provides 350 knot birdstrike resistance. This method of design was very costly, particularly when initial attempts to meet bird impact resistance goals were unsuccessful, requiring more canopies, head up display (HUD) assemblies, and more tests. Over the past decade the Air Force has invested in the development of finite element codes that simulate birdstrikes on transparency systems. This development has provided an analytical tool that can be used by engineers to evaluate the birdstrike resistance of a design before fabrication . Codes developed in the 1980s were used successfully in the design of the B-2, C-17, T-46 and V-22 transparency systems and represented a vast improvement over previous design methods, but often times analysis was slow and the programs cumbersome to use. Recently developed finite element analysis programs give the engineer greater flexibility in choosing prototype designs that meet performance goals the first time. This new generation of codes puts a design tool in the engineer's hands in which design parameters such as the number of piles in a laminated canopy, the types of materials used and individual ply thickness can be fine-tuned to achieve the desired level of birdstrike protection. The new code can be run on a variety of in-house workstations. These capabilities and the experience gained in designing the F-16 canopy are currently being used in the development of other advanced combat aircraft transparency systems. A successful fit check of the prototype F-16 canopy systems was conducted in the Flight Dynamics Directorate Transparency Durability Facility.

Acronym List

Acronym	Definition
3D	3 - Dimensional
ABDR	Aircraft Battle Damage Repair
ACC	Air Combat Command
ADP	Analytical Design Package
ADPO	Advanced Development Program Office
AEDC	Arnold Engineering Development Center
AESA	Active Electronically Scanned Arrays
AFB	Air Force Base
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AFSOC	Air Force Special Operations Command
AFTI	Advanced Fighter Technology Integration
ALC	Air Logistics Center
ALCM	Air Launched Cruise Missile
ALCOA	Aluminum Company of America
AlSiC	Aluminum Silicon Carbide
AMC	Air Mobility Command
AOA	Angle-of-Attack
ARPA	Advanced Research Projects Agency
ASC	Aeronautical Systems Center
ASIC	Application Specific Integrated Circuits
AWACS	Airborne Warning and Control System
BASH	Bird/Aircraft Strike Hazard
BE	Brilliant Eyes
BLC	Boundary Layer Control
BP	Brilliant Pebbles
BSCE	Bird Strike Committee Europe
C-HFET	Complementary Heterostructure Field Effect Transistor
CAD	Computer Aided Design
CALS	Computer-Aided Acquisition and Logistics Support
CAS	Close Air Support
CFD	Computational Fluid Dynamics
CFIT	Controlled Flight Into Terrain
COBRA	Complete Oil Breakdown Rate Analyzer
CONUS	Continental United States
CRDA	Cooperative Research and Development Agreement

Acronym	Definition
CRYOHP	Cryogenic Heat Pipe Flight Experiment
CW	Continuous Wave
D-R	Drive-Reinforcement
dB	Decibel
DMS	Desorption Mass Spectrometry
DMSO	Dimethyl Sulfoxide
DoD	Department of Defense
DTS	Digital Terrain System
FAA	Federal Aviation Administration
FCMDs	Flight Control Maintenance Diagnostics
FEWS	Follow-On Early Warning System
FIC	Fluoride Ion Cleaning
FIPS	Federal Information Processing Standard
FOD	Foreign Object Damage
GAP	Glycidyl Azide Polymer
GCAS	Ground Collision Avoidance System
GHz	Giga Hertz
GLOC	G-Induced Loss of Consciousness
GPS	Global Positioning System
GTAW	Gas Tungsten Arc Welding
HBT	Heterojunction Bipolar Transistor
HEMT	High Electron Mobility Transistor
HF	Hydrogen Fluoride
HLFO	Hybrid Laminar Flow Control
HQ	Headquarters
HUD	Head-Up Display
HVOF	High Velocity Oxy-Fuel
IC	Integrated Circuit
IDS	Integrated Data Strategy
IGBT	Insulated Gate Bipolar Transistor
IHPTET	Integrated High Performance Turbine Engine Technology
INS	Inertial Navigation System
IR	Infrared
JAST	Joint Advanced Strike Technology
JCMPO	Joint Cruise Missile Program Office
JIAWG	Joint Integrated Avionics Working Group

(continued on next page...)

Acronym List

Acronym	Definition
JSTARS	Joint Surveillance Target Attack Radar System
KSC	Kennedy Space Center
LADAR	Laser Radar
LADC	Lockheed Advanced Development Corporation
LAMARS	Large Amplitude Motion Simulators
LANTIRN	Low Altitude Navigation and Targeting Infrared for Night
LRM	Line Replaceable Module
LV	Laser Velocimetry
MANTECH	Manufacturing Technology Directorate
MAUS III	Mobile Automated Scanner
MBE	Molecular Beam Epitaxy
MCS	Manned Combat Station
MCT	MOS Controlled Thyrisitor
MDARS	Modular Data Acquisition and Recording System
MEA	More Electronic Aircraft
MMC	Metal Matrix Composite
MMST	Microelectronics Manufacturing Science and Technology
MnO_2	Manganese Dioxide
MNS	Mission Need Statement
MODGRO	Fatigue Crack Growth Prediction Software
MOS	Metal Oxide Semiconductor
mph	Miles Per Hour
MPP	Massively Parallel Processing
MS-1	Mission Simulator - 1
MTB Quat	Methyltribulylammonium Quaternary
MTBF	Mean Time Between Failure
mW	Milli Watts
NASA	National Aeronautics and Space Administration
NiCd	Nickel Cadmium
NLF	Natural Laminar Flow
OC-ALC	Oklahoma City - Air Logistics Center
PROF	Probability of Fracture
psi	Pounds per Square Inch
QPA	Qualitative Process Automation
QPAL	Qualitative Process Automation Language

Acronym	Definition
RAMTIP	Reliability and Maintainability Technology Insertion Program
REMCC	Robotic Engine Manifold Cleaning Cell
ROC	Reliable Optical Card-Edge Connector
SAE	Society of Automotive Engineers
SAIC	Science Applications International Corporation
SBRC	Hughes Santa Barbara Research Center
SDI	Strategic Defense Initiative
SiC	Silicon Carbide
SIMD	Single Instruction Multiple Data
SLCM	Sea Launched Cruise Missile
SM-ALC	Sacramento - Air Logistics Center
SOF	Special Operations Forces
SPO	System Program Office
SRAM	Static Random Access Memory
$SrCrO_4$	Strontium Chromate
SURVIAC	Survivability Information and Analysis Center
T/R	Transmit/Receive
TACS	Tactical Air Control Software
TDC	Technology Development Corporation
TDC	Thin Dense Chrome
Ti-6Al-4V	Titanium, -6 Aluminum, -4 Vanadium
TiAl	Titanium Aluminide
TMS	Tactical Mission Simulation
TRN	Terrain Referenced Navigation
UBRD	Ultrasonic Bird Repelling Device
UES	Universal Energy Systems
US	United States
USAF	United States Air Force
VFC	Vortex Flow Control
VHDL	VHSIC Hardware Design Language
VHSIC	Very High Speed Integrated Circuit
VISTA	Variable Stability In-Flight Simulator Test Aircraft
WL	Wright Laboratory
WSEP	Weapon System Evaluation Program
XMBE	Experimental Molecular Beam Epitaxy